ISEC 2018 SINGAPORE

INTERNATIONAL SCIENCE EDUCATION CONFERENCE 2018

RE-SEARCHING SCIENCE EDUCATION:
Same Issues From Different Lenses

June 19 - 21, 2018
National Institute of Education

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Jointly organised by:

Ministry of Education SINGAPORE

NIE NATIONAL INSTITUTE OF EDUCATION SINGAPORE

An Institute of NANYANG TECHNOLOGICAL UNIVERSITY SINGAPORE

TABLE OF CONTENTS

Message from Conference Co-Chairs	5
Conference Committee	6
Acknowledgements	7
General Information	8
Information for Presenters	12
Programme Overview	13
Keynote Speakers	14
• Sonya M. Martin, Seoul National University	14
• Vanessa Kind, Durham University, United Kingdom	15
• Richard Duschl, Pennsylvania State University, USA	16
• Subramanian Ramanathan, National Institute of Education, Nanyang Technological University, Singapore	17
Presentation Schedule	18
19 Jun 2018 (Day 1)	18
20 Jun 2018 (Day 2)	25
21 Jun 2018 (Day 3)	38
TradeShow Highlights	56
Synopsis of Exhibitors' Workshops (EW001 – EW011)	63
Abstracts of Presentations	67
Location Maps	306
Conference Venues	308

RE-SEARCHING SCIENCE EDUCATION:
SAME ISSUES WITH DIFFERENT LENSES

The theme "Re-searching science education: Same issues from different lenses" aims to provide a platform for intellectual dialogue on issues in science education using alternative lenses. Many problems in science education are not new, but can be addressed with new lenses to identify different or unique strategies and solutions. The word "re-search" is intentionally hyphenated to underscore the importance of constantly re-looking and re-examining previous issues so as to gain new insights into familiar problems that confront diverse stakeholders in science education. Through such a process, the field of science education will progress and be enriched.

THE INTERNATIONAL SCIENCE EDUCATION CONFERENCE 2018 (ISEC 2018) IS JOINTLY ORGANISED BY:

This conference is aimed at science education researchers, science educators, school leaders, curriculum developers, and policy makers at all levels, from elementary/primary school to tertiary institutions. The conference will offer participants opportunities to update themselves with news and views of recent developments and to exchange ideas with leading international experts in the field. Over 250 participants are expected to attend, many of whom have contributed papers for presentation at ISEC 2018 to share their findings and best practices with an international audience of teachers and academics.

ABOUT THE ISEC LOGO

The ISEC logo depicts a student's raised hand, eager to answer a question. The outstretched hand, reaching "out of the box", signifies the learner's excitement, and the quest for knowledge beyond the frontiers of science, by engaged and enthusiastic students in our classroom.

MESSAGE FROM CONFERENCE CO-CHAIRS

Tan Kim Chwee Daniel
Associate Professor

Lee Yew Jin
Associate Professor

Natural Sciences and Science Education (academic group)
National Institute of Education
Nanyang Technological University, Singapore

Science education plays an important role across the world. It assists in developing human capital to cater to the growing shift towards knowledge-based economies everywhere. Good pedagogies are hence one vital aspect towards improvements and reforms in STEM education. Teaching that make a difference is characterised by intellectual depth, which ideally should comprise of three key components, namely: cognitive depth, philosophical depth, and cultural/critical literacy. Teachers, researchers, and scientists therefore all play different, but equally pivotal roles in the success of these transformations in the classroom.

We hope that through your engagement in discussions and sharing, this conference can become a catalyst for revisiting what we hold dear in science education, both in Singapore and beyond its shores. We encourage participants in this conference to build new ties, renew old friendships, and establish new collaborations during their time in Singapore.

On behalf of the conference organising committee, we would like to express our deepest thanks to the Head of the Natural Sciences and Science Education Academic group of the National Institute of Education, Associate Professor Yan Yaw Kai for his support. Working with our many colleagues in the Ministry of Education (Singapore) has been a great privilege as well. We would also like to thank all our partners for supporting us with their kind sponsorships, and contributions of time and resources. Finally, we would like to thank all of you for attending this conference and wish that you have a very fruitful time here!

CONFERENCE COMMITTEE

ORGANISING COMMITEE

Conference Advisors	**Associate Professor YAN Yaw Kai**
Chairpersons	**Associate Professor LEE Yew Jin** **Associate Professor TAN Kim Chwee Daniel**
Secretariat	**Ms LIM Chow Tee Grace**

PROGRAMME SUB-COMMITEE

Chair	**Assistant Professor TEO Tang Wee**
Members	Mr CHIA Thien Huat Jae Dr TAN Kok Siang Dr ONG Kian Keong Aloysius Dr ONG Yann Shiou Mr YEO Leck Wee
	Associate Professor SUN Ying *Visiting Scholar, Anhui Normal University, China*
	Dr GOH Su Fen *Master Teacher, Academy of Singapore Teachers, Ministry of Education, Singapore*
	Dr TAN Hong Kim *Senior Curriculum Resource Development Specialist, Curriculum Planning and Development, Ministry of Education, Singapore*

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Members	Ms LAW Sau King Joanna

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Members	Ms CHAN-CHUA Lee Kiang Mr LIM Chee Sin Lionel Mr LIM Guo Shun Eugene Mr WONG Wai Lit	Ms CHIN Hui Jing Mr LOH Seow Boon Dr SOO Li Mei Johannah

PUBLICITY SUB-COMMITEE

Chair	**Mr TAN Ter Ming Timothy**	
Members	Dr LEE Peng Foo Peter Mr TAN Seng Chong Jason	Mr NG Yong Sim

Note: Conference committee members are staff of the Natural Sciences and Science Education academic group, National Institute of Education, unless otherwise stated.

ACKNOWLEDGEMENTS

ABSTRACT REVIEWERS

Associate Professor Josephine Shireen DESOUZA
Associate Professor LEE Yew Jin
Associate Professor TAN Aik-Ling
Assistant Professor TEO Tang Wee
Dr HOH Yin Kiong
Associate Professor HSIN Yi-Chang
Associate Professor Subramaniam RAMANATHAN
Associate Prof TAN Kim Chwee Daniel
Assistant Professor YEO Jennifer
Dr GOH Sufen

REVIEWERS FOR THE ISEC-SPRINGER BEST PAPER AWARD

Associate Professor Subramaniam RAMANATHAN
Associate Professor SUN Ying
Dr ONG Yann Shiou
Associate Professor Vanessa KIND
Associate Professor LEE Yew Jin
Associate Professor TAN Kim Chwee Daniel
Associate Professor Sonya N. MARTIN

ADMINSTRATIVE SUPPORT

Ms LIM Carol

IT SUPPORT

Ms Ellynn NG
Mr YEO Leck Wee

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GENERAL INFORMATION

TRANSPORTATION

By Bus:	From Boon Lay bus interchange, you may either take bus service 199 or 179. You may alight at the bus-stop outside Block 7 or outside Block 2.
By MRT:	Alight at Boon Lay MRT station and take bus service 179 or 199.
By Taxi:	Taxis generally cost around S$20 from town. If you are taking a taxi from campus, it is advisable to call a taxi at the Block 1 (administration block) foyer as taxis do not frequent the campus.
Self-Drive:	Parking facilities are available on campus (refer to NIE maps on p.307 for carpark locations).

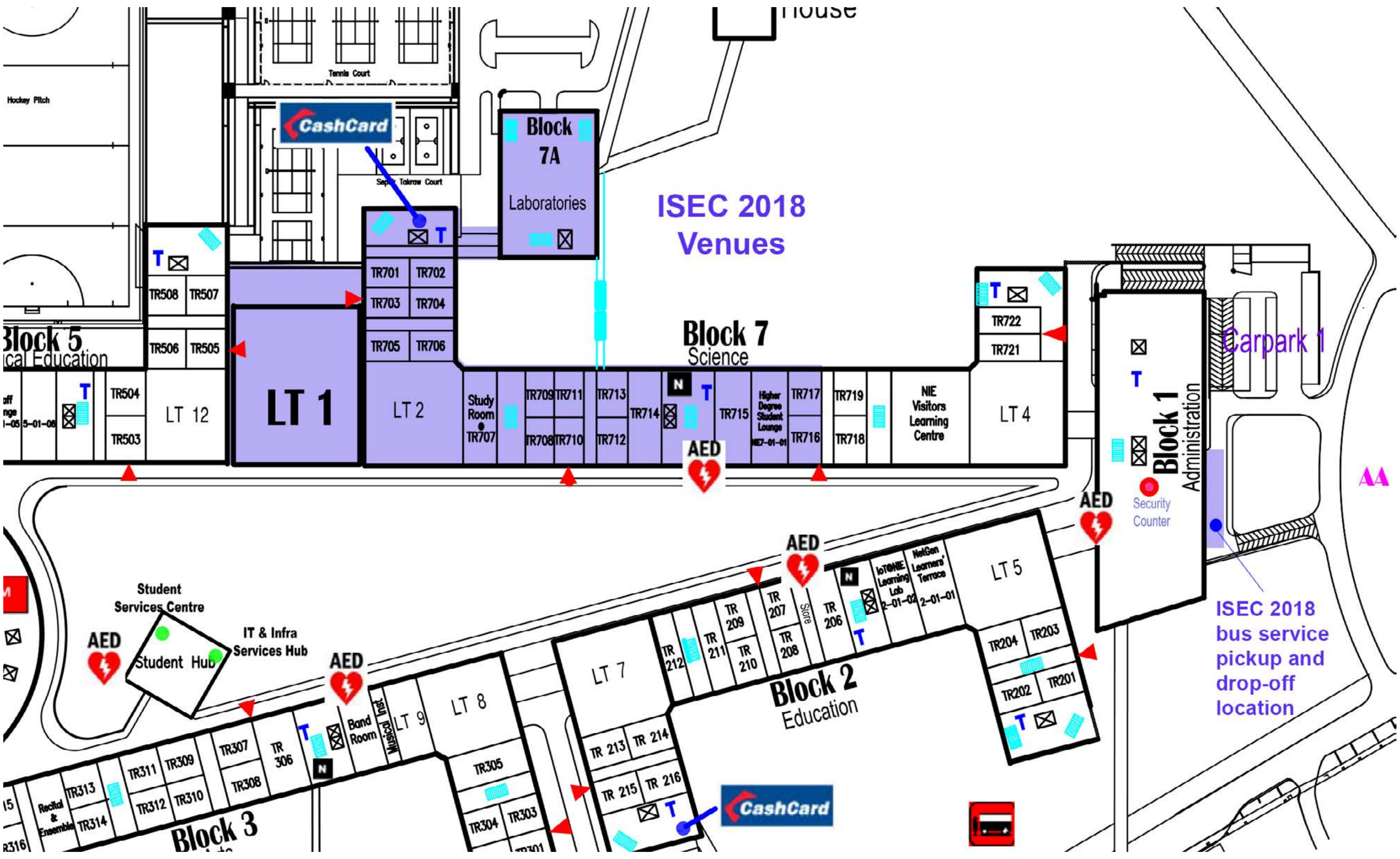
BUS SERVICE

There will be a two-way bus service to pick up participants between Boon Lay MRT station and NIE. Please note the pick-up timings and location below. To avoid missing the bus service, **participants should arrive at least 10 minutes before at the respective pickup location**. Student helpers will be stationed to direct participants. To board the bus, participants will need to **present their badge to the bus coordinator**.

No bus service will be arranged for participants attending the workshops on 19 Jun 2018, from 9am to 10:30am. Participants for the workshops will have to make their own transportation arrangement for these workshops.

Date	Pick up from Boon Lay MRT station	Pick up from NIE
19 Jun 2018 (Day 1)	12.30 pm	5.15 pm
20 Jun 2018 (Day 2)	8.00am	4.40 pm
21 Jun 2018 (Day 3)	8.00am	4.40 pm

Location map of Boon Lay MRT station and pick up location



Location map of NIE and pick up location

REGISTRATION (19 JUN 2018)

- All participants <u>must</u> register at the Registration Desk (located outside Lecture Theatre 1) to collect their badge and folder.
- Badges are to be worn throughout the conference and at mealtimes. Participants will also need to present the badge when boarding the shuttle service arranged for ISEC 2018.
- The opening hours for registration are as follow:

19 Jun 2018 (for workshops only)	0800 – 0900 hours	(Outside Lecture Theatre 1)
19 Jun 2018	1230 – 1330 hours 1500 – 1530 hours	(Outside Lecture Theatre 1)

CONFERENCE SECRETARIAT ROOM (19-21 JUN 2018)

Please feel free to enquire with the **Conference Secretariat** should you require any assistance. To contact the Secretariat, **email:** isec2018@nie.edu.sg. The opening hours for registration are as follow:

19 Jun 2018	0800 – 1700 hours	**NIE7-01-TR708** (refer to NIE map on p. 308)
20-21 Jun 2018	0900 – 1630 hours	**NIE7-01-TR708** (refer to NIE map on p. 308)

TRADESHOW (See List of Exhibitors on p. 56)

Venue:	Outside Lecture Theatre 1
Opening Hours:	0900–1700 hrs

INTERNET ACCESS

Wifi access will be provided free of charge at the conference venue. There are two types of wireless access available in NIE:

Option A: Eduroam
Option B: NIE wireless

Option A: **Eduroam**

1. For those visitors from other Eduroam institutions, please refer to the configuration guide by accessing the link: **https://itservices.nie.edu.sg/userGuide/userGuide.php**

- Click on **Staff & Students of eduroam Participating Institutions.**
- You may choose either the **Auto Configuration** by downloading the Installer Package <u>or</u> select the **Manual Setup Guides.**

2. Here's the list of participating institutions: http://www.singaren.net.sg/ed_participating_institution.php

Option B: **NIE wireless**

Your Wi-Fi login credentials are:

Network SSID:	**nieguest**
Username & Password	Please refer to the back of your badge (The username and password assigned are <u>non-transferable</u>)

Each username and password allows login on <u>one device at any one time</u>. Each participant will be issued one username and password, while an exhibitor will be issued a maximum of two usernames and passwords.

For Android mobile device:
Turn on your device's Wi-Fi → Select "**nieguest**" Wi-Fi network → Enter your **credentials** for Wi-Fi connection

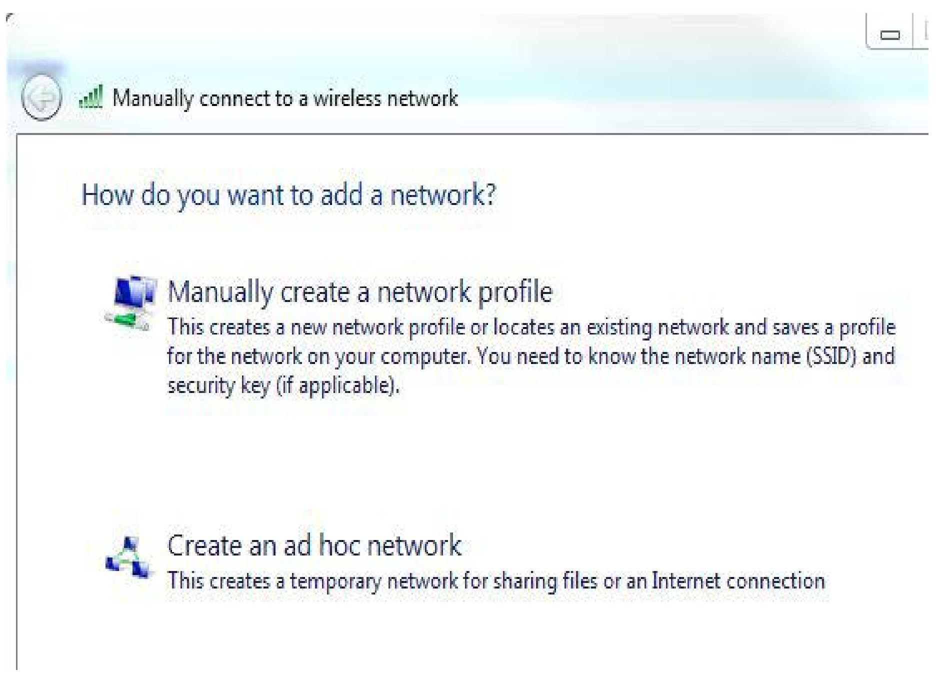
- Phase 2 authentication: MSCHAPV2
- Identity: Enter your **Username** (please refer to the back of your badge)
- Password: Enter your **Password** (please refer to the back of your badge)

For iOS mobile device:
Turn on your device's Wi-Fi → Select "**nieguest"** Wi-Fi network → Enter your **credentials** for Wi-Fi connection (click on Accept to verify *.nie.edu.sg certificate)

For Mac laptop:
Turn Airport On → Select "**nieguest**" Wi-Fi network → Enter your **credentials** for Wi-Fi connection.

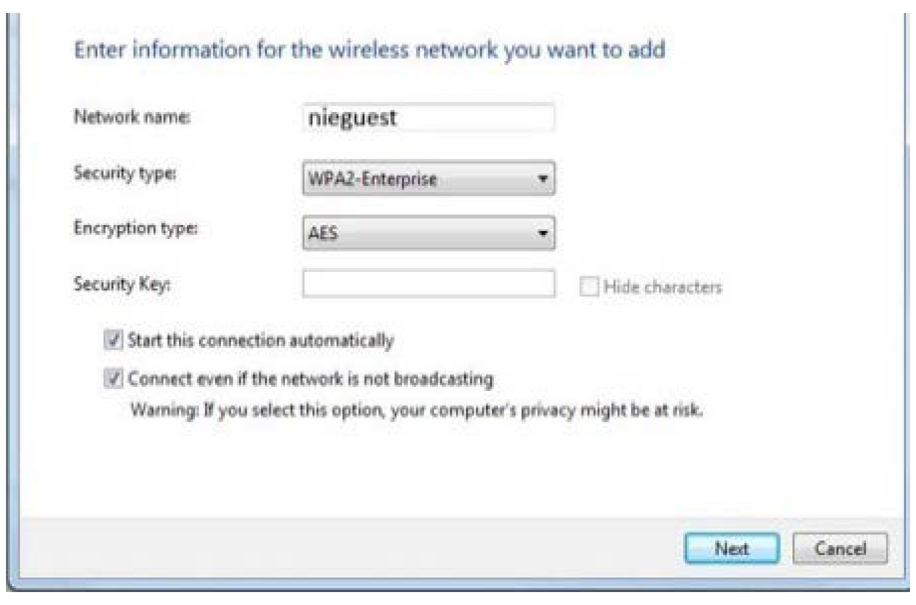
For Windows laptop (Using Windows 7 as a reference):

1. Turn on your laptop's Wi-Fi → Go to **Control Panel** → **Network and Sharing Center** → **Manage Wireless network** and click **Add** button → Click **Manually create a network profile**



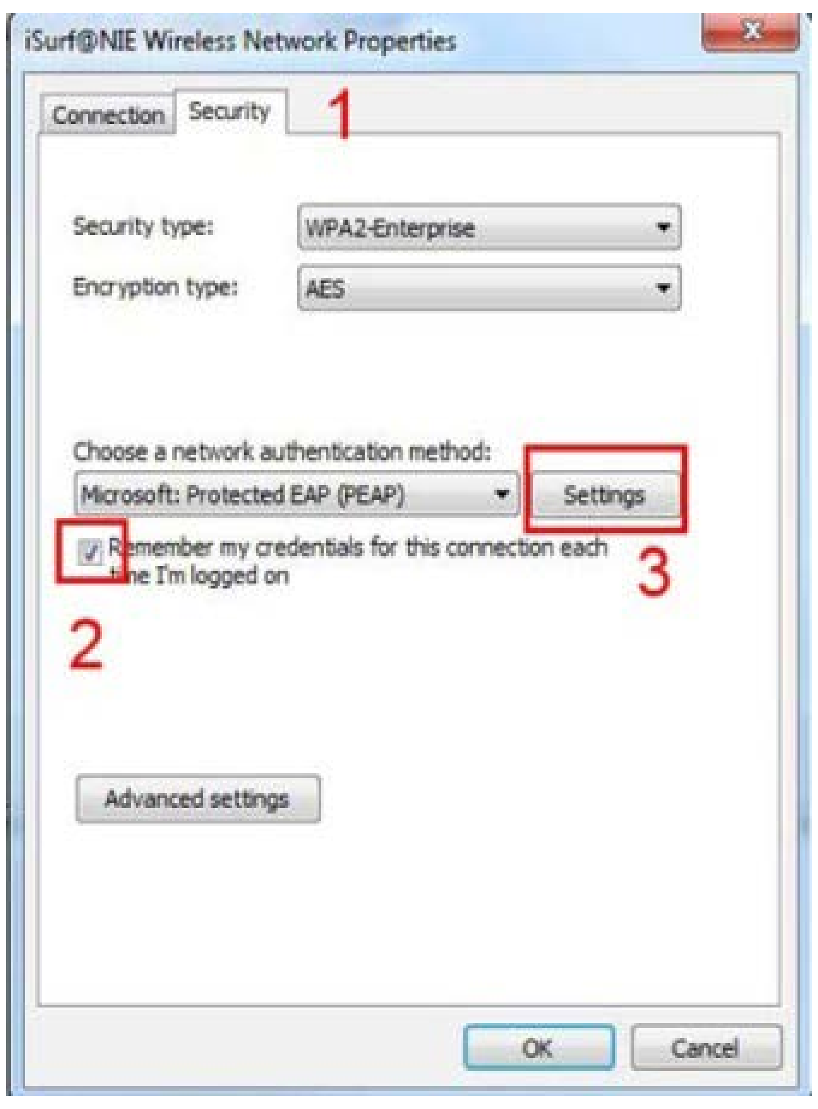
Note: For **Win 8** and above, Go to **Search Apps** → **Control Panel** → **Network and Sharing Center** → **View network status and tasks** → **Set up a new connection or network** → **Manually connect to a wireless network**

2. Supply the information below and then click **Next** button:-
   - Network name: **nieguest** (in lower-case)
   - Security type: **WPA2-Enterprise**
   - Security type: **AES**
   - Start this connection automatically: **Check**
   - Connect even if the network is not broadcasting:**Check**



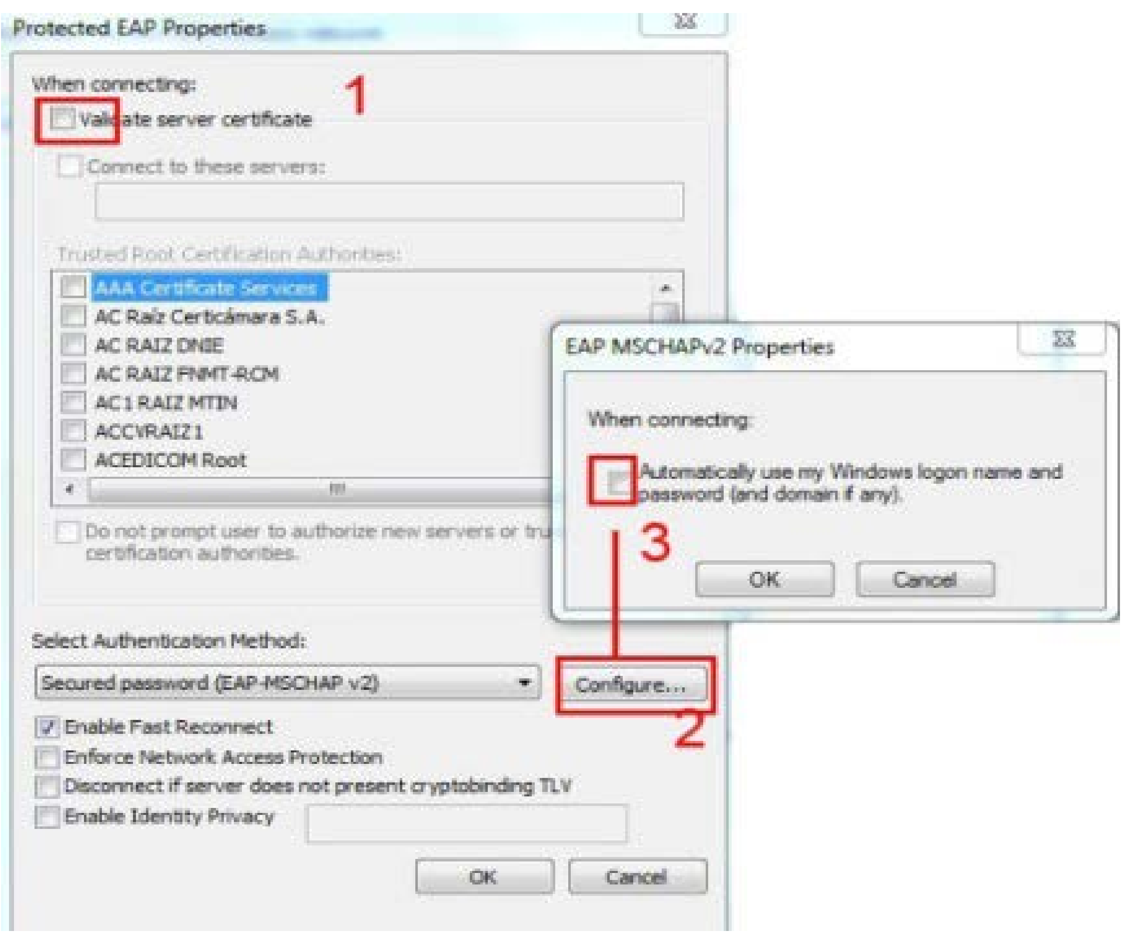
INTERNET ACCESS

3. Successfully added **nieguest** message pop-up. Click **Change connection settings**.
4. Click on **Security** (1) tab.
5. Check **Remember my credentials for this connection each time I'm logged on** (2).
6. Click **Settings** (3) button



7. Uncheck **Validate server certificate** (1)
8. Click **Configure** (2) button
   - Uncheck **Automatically use my Windows logon name and password (and domain if any)** (3).
   - Click **OK** button to accept all the settings.

9. Connect to "**nieguest**" Wi-Fi network and enter your **credentials** for Wi-Fi connection.



MEALS

All food served is Halal. Each participant will be entitled to one packed meal box per lunch/tea. To collect the meal boxes, participants will need to present the meal coupons found at the back of their badge. **Please do not lose the meal coupons as they are not replaceable.**

MEDICAL SERVICES

If you are feeling unwell and need medical attention, you may refer to the following medical centre located on campus. Cost varies depending on the type of consultation and medication.

Medical Centre	Location	Operating Hours	Telephone
Fullerton Health @ NTU	Nanyang Technological University 36 Nanyang Avenue #01-01 Singapore 639801	Mon to Fri 0830–2100 hrs Sat 0930–1300 hrs	6793 6828 / 6793 6338 (please call for an appointment)
West Point Hospital	235 Corporation Drive Singapore 619771 (10min drive from NIE)	Operates 24 hrs	62625858
My Family Clinic	Block 638 Jurong West St 61 #02-09 Pioneer Mall Singapore 640638	Daily 0800–1300 hrs 1400–1700 hrs 1800–2200 hrs	68611182

INFORMATION FOR PRESENTERS

FACILITIES

Every room will have a desktop PC (Windows 10, with internet access) and projector. There will also be a standard VGA cable to allow your own laptop to be connected. Some rooms may have HDMI connectors, but this is not guaranteed. Other presentation accessories such as display adapters for MacBooks, laser pointers or remotes will not be provided. Power supply is ~230V with a UK- style 3-pin socket.

YOUR PRESENTATION

Each 90 minute session will typically have up to three paper presentations. You may wish to prepare some handouts for your audience. Please be on time and do not swap sessions without informing the organiser. Some audience might stream in and out of a session. Wear your badges throughout the conference.

ROLE OF CHAIRPERSON FOR PAPER PRESENTATIONS

The chairperson during a paper presentation session is the last presenter. His/her role is to introduce the session and the presenters and to keep the session to time. At the beginning of the session, please provide a brief introduction to the session and welcome all conference participants. Each speaker has 20 minutes followed by 5-10 minutes of questions. The chairperson can give a warning when there are 5 minutes remaining so that all the presentations can end on time.

Please do not begin the presentations earlier as other people from other sessions may wish to attend the talk.

POSTER PRESENTATIONS (21 JUN 2018, 10.30AM – 12.00PM)

Poster size: A1 (approximately 65 cm wide by 80 cm high, or 25 $^1/_2$" by 31 $^1/_2$"). The design and layout of the poster is left to the discretion of the presenter, however, each poster is required to contain a panel listing the title of the abstract, the name(s) of the author(s) and institutional affiliations(s). Posters can be attached to the panel boards by Velcro tapes or pins, which will be provided by the organiser. There will be no table space and power points around the booth for display of artifacts or laptops.

Please put up your poster on **19 June 2018 (Day 1) between 3.00pm - 5.30 pm or 20 Jun 2018 (Day 2) between 08.30am - 09.30am** at **NIE7-02-01 (Science Education Lab 1)** and remove them after lunch on 21 June 2018.

Any posters not removed by 3.00 pm on 21 Jun 2018 will be discarded.

PROGRAMME OVERVIEW

Time	Day 1 19 June 2018	Day 2 20 June 2018	Day 3 21 June 2018
0800 – 0830	WORKSHOP REGISTRATION (Outside LT1)		
0830 – 0900			
0900 – 0930	3 Concurrent Workshops (TR 701 – 702, NIE 7A–B2–10)	Morning Tea	Morning Tea
0930 – 1000		Keynote 2 Vanessa Kind (LT1)	Keynote 4 Subramaniam Ramanathan ISEC Springer Best Paper Award Ceremony (LT1)
1000 – 1030			
1030 – 1100	Workshop TEA	Concurrent Session 2 (TR 701 – 706; TR 709 – 712; TR 714 –717; NIE3–B1–21)	Poster Presentation (NIE7–02–01)
1100 – 1130	3 Concurrent Workshops (Continuation TR 701–702, NIE 7A–B2–10)		Meet-the-Editors Session (TR 701) / LUNCH
1130 – 1200			
1200 – 1230		LUNCH	LUNCH
1230 – 1300	CONFERENCE REGISTRATION (outside LT1)		Concurrent Session 4 (TR 701 – 706; TR 709 – 715)
1300 – 1330			
1330 – 1400	Opening Ceremony (LT1)	Keynote 3 Richard Duschl (LT1)	
1400 – 1430	Keynote 1 Sonya N. Martin (LT1)	Concurrent Session 3 (TR 701 – 706; TR 709 –716; NIE7A–B1–03)	Afternoon Tea
1430 – 1500			
1500 – 1530	Afternoon Tea		Concurrent Session 5 (TR 701 – 706; TR 709 –714)
1530 – 1600	Concurrent Session 1 (TR 701 – 706; TR 709 – 715; NIE7A-B1-03)	Afternoon Tea	
1600 – 1630			
1630 – 1700			

KEYNOTE SPEAKERS

Sonya N. Martin, Seoul National University, Korea
Day 1, 19 Jun 2018, 1400–1500 hrs,
Lecture Theatre 1, NIE

Sonya N. Martin is an Associate Professor of Science Education faculty at the Seoul National University in Seoul, Republic of Korea. Prior to moving to Korea, Dr. Martin was a tenured faculty member at Drexel University in Philadelphia, PA in the United States where she was the Principal Investigator of a National Science Foundation (NSF)-funded (HRD 1036637) study examining the intersections of gender, ethnicity, and language learning in the context of middle school science.

Her focus in G-SPELL (Gender and Science Proficiency for English Language Learners) was on identifying science teacher practices that promoted language learning in the context of science inquiry with English Language Learners. She became particularly interested in exploring ways to improve collaborative teaching between science content and ESL teachers to promote beneficial science teaching practices for all students. In addition, she became interested in the science education experiences of the students in the study who had recently immigrated to Philadelphia from Asian countries.

To learn more about science education in Asia, Dr. Martin accepted an international faculty position at Seoul National University and moved to Korea in 2011. Since then, she has been studying Korean and actively engaging in collaborative research with colleagues in Asia. Dr. Martin has several funded projects in Korea that focused on equity issues in science education, including research about KSL students, special education needs students, and research focused on understanding the impact of culture on science teaching and learning in Korea, Taiwan, and Singapore.

Dr. Martin is a co-founder and Co-Editor of Asia-Pacific Science Education and she serves as an editorial board member for several journals, including *Journal of Research in Science Teaching, Research in Science Education, Journal of Science Teacher Education, and Cultural Studies of Science Education,* and *EURASIA journal*. She also serves as a Board Member for the Korean Association of Science Education (KASE) and for the International Society of Educational Research (iSER). Finally, Dr. Martin serves as a faculty advisor for international students at her college and is engaged in several college and university level initiatives aimed at improving internationalization efforts.

Confronting Prevailing Narratives of Student Engagement and Participation in Science Classrooms from Different Lenses

In this presentation, Sonya uses a sociocultural lens to examine how societal structures shape expectations about engagement and participation practices in schools and science classrooms. Using quantitative measures (surveys measuring students' perceptions of classroom participation) and qualitative methods (classroom observation, video analysis, interviews with teachers and students), She offers cross-cultural comparisons to raise questions about the need to re-consider supposed connections that exist between student interest, classroom participation, and achievement in science. Sonya also offers examples from research in Korea and Taiwan that differ from the prevailing narrative that students' enjoyment and interest in science are key factors for promoting cognitive engagement and high achievement in science. Building from my discussion of this phenomenon, Sonya argues the need for science education researchers to critically question some of the hegemonic assumptions that underpin research on student engagement and participation in science. In particular, she suggests that there needs to be a stronger emphasis on the contextualized ways in which participation can be demonstrated and offers the issue of student silence as but one example of how researchers can begin to expand our perspectives about how science is learned in different contexts.

Vanessa Kind, Durham University, United Kingdom
Day 2, 20 Jun 2018, 0930–1030 hrs, NIE7A-B2-10, NIE

Associate Professor Vanessa Kind studied biochemistry and worked in molecular biology prior to becoming a chemistry teacher. This led to her interest in the impact of teacher knowledge on student achievement. Vanessa's doctorate study investigated longitudinal changes in understanding occurring in post-16 chemistry students, leading to the development of novel teaching strategies for specific concepts. Vanessa tested these as head of chemistry (and physics) in a Hull sixth form college. Through lectureship in science education at the Institute of Education, Vanessa became a science teacher educator. After headship of an international school in Norway, she joined Durham in January 2005. Vanessa's current research explores how teachers' science subject knowledge, beliefs, views about science, self-confidence and attitudes impact on teaching and student learning outcomes. She contributes to international debate surrounding the nature of teacher knowledge and connections between science teacher education policy and practice. Current projects include a UK-wide study of practical work in science funded by Gatsby Charitable Foundation; development of chemistry teacher knowledge in South Africa, supported by a British Academy Newton Mobility Grant; and a Wellcome Trust People Award held with Durham Law School on students' understandings of stem cell research and human cloning via the medium of law. Previous work includes interdisciplinary projects with colleagues in medieval history and archaeology law, exploring educational perspectives on medieval interpretations of natural phenomena and early perceptions of light, and development of a diagnostic test of chemistry teachers' subject knowledge for the Royal Society of Chemistry.

Pedagogical content knowledge: lessons from research and policy for improving teaching quality

The lecture discusses the expectations societies have for their teachers, introducing factors required for "quality teaching". Current teacher preparation methodologies in many nations operate a deficit model that focuses on providing potential teachers with information deemed necessary to function as a teacher, allied to a "master-apprentice" system to develop classroom teaching strategies. The impact on student achievement is mixed: international data shows that some well-funded jurisdictions perform at or below average, and outcomes for students vary. The lecture explores research evidence illustrating "great teaching", identifying components that seem consistently essential for high attainment. Pedagogical content knowledge is presented, and analysed from the perspective of teacher preparation policies in five contrasting jurisdictions. Empirical evidence illustrating the quality of pedagogical content knowledge that teachers require will be presented. The lecture concludes with a proposal for a teacher quality framework model and recommendations for policy and practice.

Richard Duschl, Pennsylvania State University, USA
Day 2, 20 Jun 2018, 1330–1430 hrs,
Lecture Theatre 1, NIE

Professor Richard A. Duschl, (Ph.D. 1983 University of Maryland, College Park) is the Waterbury Chair Professor of Secondary Education at Pennsylvania State University. Prior to joining Pennsylvania State University, Richard held the Chair of Science Education at King's College London and served on the faculties of Rutgers, Vanderbilt and the University of Pittsburgh. He chaired the National Research Council research synthesis report *Taking Science to School: Learning and Teaching Science in Grades K-8* (NRC, 2007) and was a member of the Next Generation Science Standards national leadership team; co-chairing the Earth/Space Sciences writing team. With Richard Grandy, he co-edited Teaching Scientific Inquiry: Implications for Research and Implementation. With Amber Bismack, he co-edited Reconceptualizing *STEM* Education – The Central Role of Practices, which is a report of the 2013 Waterbury Summit. From 2008 to 2011, he was NARST President. For a decade he served as editor of Science Education. From November 2012 to December 2014, Richard joined the National Science Foundation in the Directorate of Education and Human Resources (EHR) as Director, Division of Research on Learning and as Senior Advisor in EHR. His research interests focuses on establishing epistemic learning environments and on the role of students' inquiry and argumentation processes. Richard has twice received the 'JRST Award' (1989; 2003) for the outstanding research article published in the *Journal of Research in Science Teaching* and in 2015 he received the prestigious *NARST Distinguished Contributions to Science Education Research Through Research Award.*

The Role of Argumentation Discourse in the Design of Knowledge-building Learning Experiences and Environments

Arguments have three forms – analytical, dialectical, and rhetorical – each of which has a role in building scientific knowledge. Argumentation discourse is a core practice in the learning and doing of science. Doing science is fundamentally about building and refining knowledge; e.g. models, mechanisms, and explanations. Knowledge building occurs within and among communities of practice whose members engage in an array of critique and communication practices. The keynote address will examine how philosophical, psychological, and pedagogical developments in the 20th century have informed designs for argumentation frameworks that, in turn, have shaped our thinking about STEM teaching and learning and the design of STEM learning environments. The 'Three Part Harmony' model of infusing and balancing conceptual, epistemic, and social learning goals is introduced as a set of principles for the design of curriculum, instruction, and assessments frameworks. These frameworks are then examined to foster the development of and engagement in productive disciplinary discourse practices – argumentation chief among them.

Subramanian Ramanathan, National Institute of Education, Nanyang Technological University, Singapore
Day 3, 21 Jun 2018, 0930–1030 hrs,
Lecture Theatre 1, NIE

Associate Professor R. Subramaniam is with the Natural Sciences & Science Education Academic Group at the National Institute of Education in Nanyang Technological University in Singapore. His current principal research interests are in the areas of chemistry education, physics education, primary science education, science education, and science communication. He has been the principal investigator for a number of funded research projects, and has so far graduated five PhD students.

Students' Learning in the Sciences

Students' understanding in the sciences – whether it is in physics, chemistry or biology, is often fraught with learning difficulties and alternative conceptions. Just because students can answer a question correctly does not necessarily mean that their understanding matches canonical equivalence. It is quite likely that their learning may have conceptual gaps that are worth bridging. Subramaniam will elaborate more on this in his presentation. Also, Subramaniam argued for more linkages to be forged between schools and informal science institutions as a way to improve attitudes towards science among students as well as for students' learning in the sciences to benefit from the designed settings that these institutions bring to bear on the learning space.

PROGRAMME SCHEDULE

Day 1
19 JUNE

PRE-CONFERENCE WORKSHOPS

Venue & Time	Workshop title	Authors
TR701 0900-1200h	Workshop 1: Using Video Analysis to Reframe Research on Classroom Interactions	**Sonya N. MARTIN** *Seoul National University*
TR702 0900-1200h	Workshop 2: Infusing argumentation in Planning and Carrying Out Investigations: The 'E-E' continuum and 5D Model	**Richard DUSCHL** *Pennsylvania State University*
NIE 7A-B2-10 0900-1200h	Workshop 3: Students' Difficulties with Chemistry Equilibrium	**Vanessa KIND** *Durham University*

KEYNOTE PRESENTATION 1

Venue & Time	Keynote title	Authors
LT1 1400-1500h	Confronting Prevailing Narratives of Student Engagement and Participation in Science Classrooms from Different Lenses Read abstract	**Sonya N. MARTIN** *Seoul National University*

PRESENTATION SCHEDULE

Day 1
19 JUNE

CONCURRENT SESSION 1

Concurrent 1.1 (Paper) Strand: Science Teaching and Learning

Venue & Time	Paper title	Authors
TR701 1530 - 1600h	(A259) Grade 10 students' efficacy on Learning and innovation skills Read abstract	**Sirawut CHANACHAI** *Kasetsart University* **Akarat TANAK** *Kasetsart University* **Chomdao SINTHUVANICH** *Kasetsart University*
TR701 1600 - 1630h	(A269) Exploring 10th grade students' scientific creativity in ecosystem learning unit Read abstract	**Sitticherd BUNPAPANPONG** *Kasetsart University* **Chittamas SUKSAWANG** *Kasetsart University* **Ekaphan KRAICHAK** *Kasetsart University*
TR701 1630 - 1700h	(A297) The Waste - Interdisciplinary Content in Chemistry Education Read abstract	**Melánia FESZTEROVÁ** *Constantine the Philosopher University in Nitra* **Marta KUHNOVÁ** *University of Ss. Cyril and Methodius in Trnava* **Lýdia PORUBCOVÁ** *Constantine the Philosopher University in Nitra*

Concurrent 1.2 (Paper) Strand: Science Teaching and Learning

Venue & Time	Paper title	Authors
TR702 1530 - 1600h	(A215) Assessing Grade 11 Students' Abilities to Give Scientific Explanation about the Endocrine System: The Potential Support of Socioscientific Issues-Based Teaching for Student's Constructing Scientific Explanation Read abstract	**Onnicha HONGKERD** *Kasetsart University* **Sasithep PITIPORNTAPIN** *Kasetsart University* **Pramote CHUMNANPUEN** *Kasetsart University*
TR702 1600 - 1630h	(A262) Exploring Scientific Argumentation Skills of Grade 12 Student in the Unit of Hormones Read abstract	**Methanon SANGACHAT** *Kasetsart University* **Ekgapoom JANTARAKANTEE** *Kasetsart University* **Wirasak FUNGFUANG** *Kasetsart University*
TR702 1630 - 1700h	(A413) Providing language support to help Primary Six students write better explanations in Science Read abstract	**Alison TAN** *Ministry of Education, Singapore* **Jonathan LO** *Endeavour Primary School* **Cai Ying LOH** *Endeavour Primary School*

Day 1
19 JUNE

CONCURRENT SESSION 1

Concurrent 1.3 (Paper) Strand: Science Teaching and Learning

Venue & Time	Paper title	Authors
TR703 1530 - 1600h	(A258) Hands-on learning experiences for primary science students: a study on the effectiveness on learning physical science Read abstract	**Pei Ling GO** *Ministry of Education, Singapore*
TR703 1600 - 1630h	(A231) Investigating Graduate Students' Knowledge Structures for Scientific Models Read abstract	**Hsin-Yi CHANG** *National Taiwan Univeristy of Science and Technology* **Chin-Chung TSAI** *National Taiwan Normal University*
TR703 1630 - 1700h	(A342) Promoting Self-Directed Learning (SDL) and Assessment as Learning (AaL) in Science Education in Hong Kong Read abstract	**Chui-ling Tracy CHEUNG** *The University of Hong Kong* **Kai-yip Michael TSANG** *Yuen Long Merchants Association Secondary School*

Concurrent 1.4 (Paper)
Strand: Science Teacher Professional Development and Teacher Education

Venue & Time	Paper title	Authors
TR704 1530 - 1600h	(A193) Exploring Pre-service Science Teachers' Reflective Quality on Inquiry-based Learning within a Professional Learning Community Read abstract	**Jeerawan KETSING** *Kasetsart University* **Noriyuki INOUE** *Waseda University* **Sandy BUCZYNSKI** *University of San Diego*
TR704 1600 - 1630h	(A301) Exploring a Professional Development Program for Elementary Science Teachers: An International Partnership Read abstract	**Jeni DAVIS** *Salisbury University* **Katie LAUX** *University of South Florida*
TR704 1630 - 1700h	(A288) Pre-service teachers' enacted topic specific pedagogical content knowledge in relation to learner performance Read abstract	**Olutosin Solomon AKINYEMI** *University of the Witwatersrand* **Elizabeth MAVHUNGA** *University of the Witwatersrand*

Day 1
19 JUNE

CONCURRENT SESSION 1

Concurrent 1.5 (Paper)
Strand: Science Teacher Professional Development and Teacher Education

Venue & Time	Paper title	Authors
TR705 1530 - 1600h	(A179) Paying attention in class: What do science teachers take note of in the classroom? Read abstract	**Melvin CHEW** *National Institute of Education, Nanyang Technological University, Singapore* **Aik Ling TAN** *National Institute of Education, Nanyang Technological University, Singapore* **Seng Chee TAN** *National Institute of Education, Nanyang Technological University, Singapore*
TR705 1600 - 1630h	(A252) Teacher's Dilemma: Allow Questioning in lessons? Read abstract	**Erkan POLATDEMIR** *Hwa Chong Institution*
TR705 1630 -1700h	(A276) Teaching integration of 5E learning cycle and flower components Read abstract	**Thasaneeya Ratanaroutai NOPPARATJAMJOMRAS** *Mahidol University* **Suchai NOPPARATJAMJOMRAS** *Mahidol University*

Concurrent 1.6 (Paper)
Strand: Science Teacher Professional Development and Teacher Education

Venue & Time	Paper title	Authors
TR706 1530 - 1600h	(A235) An empowerment evaluation approach in shifting a South African science teacher towards an inquiry-based pedagogy Read abstract	**Umesh RAMNARAIN** *University of Johannesburg* **Nceba MAKHUBALO** *University of Johannesburg*
TR706 1600 - 1630h	(A270) Pre-Service Science Teachers' Views About the Nature of STEM (NOSTEM): A Comparative Study Between Thailand and Japan Read abstract	**Chatree FAIKHAMTA** *Kasetart University* **Yoshisuke KUMANO** *Shizuoka University*
TR706 1630 - 1700h	(A277) Using Classroom Action Research to promote Preservice Teachers' Pedagogical Content Knowledge for Inquiry-based Learning in Science Methods Course Read abstract	**Siriphan SATTHAPHON** *Petchaburi Rajabhat University* **Pattamaporn PIMTHONG** *Kasetsart University* **Teerasak WEERAPASPONG** *Kasetsart University*

Day 1
19 JUNE

CONCURRENT SESSION 1

Concurrent 1.7 (Paper) Strand: Science in Informal Settings

Venue & Time	Paper title	Authors
TR709 1530 - 1600h	(A265) Experiential Learning & Environmental Literacy Read abstract	**Liyun WONG** *Pioneer Primary School* **Ahmad FAIRUZI** *Pioneer Primary School* **Norhisham SAADON** *Pioneer Primary School*
TR709 1600 - 1630h	(A307) Traditional Knowledges of Local Wisdom of Kampung Naga (Ciamis, Indonesia) about Environmental Conservation and Sanitation Read abstract	**Hertien SURTIKANTI** *Universitas Pendidikan Indonesia*

Concurrent 1.8 (Paper) Strand: History, Philosophy, and Sociology

Venue & Time	Paper title	Authors
TR710 1530 - 1600h	(A219) Multi-faceted Meaning of Scientific Literacy from Five Theoretical Perspectives Read abstract	**Sophia JEONG** *University of Georgia* **Gretchen KING** *University of Nebraska–Lincoln* **David PAULI** *University of Georgia* **Cary SELL** *University of Georgia* **David STEELE** *University of Georgia* **J. Steve OLIVER** *University of Georgia*
TR710 1600 - 1630h	(A225) An Analysis of Korean “Science Inquiry and Experiment” Textbooks’ Representations of the Nature of Science Read abstract	**Seungran YANG** *Seoul National University* **Wonyong PARK** *Seoul National University* **Jinwoong SONG** *Seoul National University*

Day 1
19 JUNE

CONCURRENT SESSION 1

Concurrent 1.9 (Paper) Strand: Assessment and Evaluation

Venue & Time	Paper title	Authors
TR711 1530 - 1600h	(A214) Role of formative assessment in strengthening pupils' understanding of simple circuits by a Professional Learning Community Read abstract	**Mohamed Azhar MOHAMED NOOR** *Innova Primary School*
TR711 1600 - 1630h	(A256) Development of Two-Tier Diagnostic Test to Identify Students' Understanding in Working Principles and Applications of Bipolar Junction Transistors Read abstract	**Thasaneeya Ratanaroutai NOPPARATJAMJOMRAS** *Institute for Innovative Learning* **Myat Noe KHIN** *Institute for Innovative Learning* **Suchai NOPPARATJAMJOMRAS** *Institute for Innovative Learning* **Ratchapak CHITTAREE** *Institute for Innovative Learning*
TR711 1630 - 1700h	(A325) Do Enjoyment and Self-efficacy in Science affect Academic Achievement? Read abstract	**Martina DICKSON** *Emirates College for Advanced Education* **Shaljan AREEPATTAMANNIL** *Emirates College for Advanced Education*

Concurrent 1.10 (Workshop) Strand: Assessment and Evaluation

Venue & Time	Paper title	Authors
TR712 1530 - 1700h	(W362) Design and Implementation of a Two-tier Multiple Choice Questionnaire to Assess Understanding of Evolution Concepts Read abstract	**Kah Huat Robin SEOH** *NUS High School of Math and Science*

Concurrent 1.11 (Workshop) Strand: Science Teaching and Learning

Venue & Time	Paper title	Authors
TR713 1530 - 1700h	(W353) The Mirror has Two Faces: Using "Team-based Learning" as a pedagogical approach from both the instructor and student's perspectives Read abstract	**Emmanuel TAN** *Lee Kong Chian Schol of Medicine, Nanyang Technological University, Singapore* **Preman RAJALINGAM** *Lee Kong Chian Schol of Medicine, Nanyang Technological University, Singapore*

Day 1
19 JUNE

CONCURRENT SESSION 1

Concurrent 1.12 Carolina Biological Consultancy (Exhibitor's Workshop)

Venue & Time	Paper title
NIE 7A-B1-03 1530-1700h	(EW001) STEM Applied Learning Programmes Read abstract

Concurrent 1.13 Labquip (S) Pte Ltd (Exhibitor's Workshop)

Venue & Time	Paper title
TR714 1530-1700h	(EW002) Wireless probeware technology in Science - with hands-on Read abstract

Concurrent 1.14 Leave a Nest Singapore Pte. Ltd (Exhibitor's Workshop)

Venue & Time	Paper title
TR715 1530-1700h	(EW003) Be an engineer to design future Read abstract

Day 2

20 JUNE

CONCURRENT SESSION 2

KETNOTE PRESENTATION 2

Venue & Time	Keynote title	Authors
LT 1 0930 - 1030h	Pedagogical content knowledge: lessons from research and policy for improving teaching quality Read abstract	**Vanessa KIND** Durham University

Concurrent 2.1 (Paper) Strand: Science Teaching and Learning

Venue & Time	Paper title	Authors
TR701 1030 - 1100h	(A304) Interest in STEM Careers: A Comparison between Primary and Secondary School Students Read abstract	**Norsharani ABDUL RAHMAN** *Universiti Kebangsaan Malaysia* **Illey Izyani IBRAHIM** *Universiti Kebangsaan Malaysia* **Lilia HALIM** *Universiti Kebangsaan Malaysia*
TR701 1100 - 1130h	(A339) Consideration of the disciplinary nature of STEM education: a required pedagogical approach Read abstract	**Gillian KIDMAN** *Monash University* **Niranjan CASINADER** *Monash University*
TR701 1130 - 1200h	(A417) How do I develop 5-grade students' collaborative skills using Science, Technology, Engineering and Mathematics (STEM) Education?: Classroom Action Research Read abstract	**Panuvit CHANTARA** *Kasetsart University* **Sasithep PITIPORNTAPIN** *Kasetsart University*

Day 2

20 JUNE

CONCURRENT SESSION 2

Concurrent 2.2 (Paper) Strand: Science Teaching and Learning

Venue & Time	Paper title	Authors
TR702 1030 - 1100h	(A334) Embedding Multiple Modes of Representations in Open Ended Test on Transition Element Read abstract	**Mageswary KARPUDEWAN** *Universiti Sains Malaysia* **Nilavathi BASASUNDRAM** *Universiti Sains Malaysia*
TR702 1100 - 1130h	(A395) Uniqueness of Senior High School Students' Sequence Expressions of Triangle of Representation in Electrochemistry Read abstract	**Chontawat MEEDEE** *Khon Kaen University* **Romklao JANTRASEE** *Khon Kaen University*
TR702 1130 - 1200h	(A422) Students' conceptions related to bonding in ionic compounds: an interventional study using multiple representations to explore and reconstruct students' ideas Read abstract	**Sitalakshmi RAMAMURTHI** *University of Delhi*

Concurrent 2.3 (Paper) Strand: Science Teaching and Learning

Venue & Time	Paper title	Authors
TR703 1030 - 1100h	(A205) High School Students' Learning Progression in Carbon Cycle Read abstract	**Thanasak KONGKOEY** *Kasetsart University* **Boonsatien BOONSOONG** *Kasetsart University* **Jeerawan KETSING** *Kasetsart University*
TR703 1100 - 1130h	(A368) Physics learning through the use of progressive multiple representations Read abstract	**Leticia GALLEGOS-CÁZARES** *Universidad Nacional Autónoma de México* **Fernando FLORES-CAMACHO** *Universidad Nacional Autónoma de México* **César ARIAS-NAVARRETE** *Universidad Nacional Autónoma de México*
TR703 1130 - 1200h	(A410) An Analysis of Teaching Methods in Science Lessons: Based on the Results of National Assessment of Academic Ability in Japan Read abstract	**Takuya MATSUURA** *Hiroshima University* **Hiroyoshi KINOSHITA** *Hiroshima University*

Day 2
20 JUNE

CONCURRENT SESSION 2

Concurrent 2.4 (Paper) Strand: Science Teaching and Learning

Venue & Time	Paper title	Authors
TR704 1030 - 1100h	(A367) Effects of School Science Laboratories with ICT on High School Students' Representations of Scientific Knowledge in Daily School Context Read abstract	**Fernando FLORES-CAMACHO** *Universidad Nacional Autónoma de México* **Leticia GALLEGOS-CÁZARES** *Universidad Nacional Autónoma de México* **César ARIAS-NAVARRETE** *Universidad Nacional Autónoma de México*
TR704 1100 - 1130h	(A394) Analyzing the Use of Evolutionary Trees (Tree Thinking) with Middle School Students Read abstract	**Gonzalo PEÑALOZA** *Maloka Science Center, Bogotá* **Jairo ROBLES-PIÑEROS** *Federal University of Bahía*

Concurrent 2.5 (Paper)
Strand: Science Teacher Professional Development and Teacher Education

Venue & Time	Paper title	Authors
TR705 1030 - 1100h	(A228) A professional development tool to enhance science teachers' thinking and reasoning about their practice Read abstract	**Ravindran S.** *Ministry of Education, Singapore* **Chor Yam LAU** *Ministry of Education, Singapore* **Pei Yun TAY** *Yusof Ishak Secondary School*
TR705 1100 - 1130h	(A302) Science teacher preparation via blended and face to face programmes: A comparison of teachers' professional learning and sense of efficacy before and after the practicum Read abstract	**Marcia RAINFORD** *University of the West Indies*
TR705 1130 - 1200h	(A308) Enhancing Advanced Placement Physics Teachers' Knowledge Base Read abstract	**Justina OGODO** *The Ohio State University*

Day 2
20 JUNE

CONCURRENT SESSION 2

Concurrent 2.6 (Paper)
Strand: Science Teacher Professional Development and Teacher Education

Venue & Time	Paper title	Authors
TR706 1030 - 1100h	(A173) Facilitating the use educational research by teachers to address concerns in practice Read abstract	**Kim Chwee Daniel TAN** *National Institute of Education, Nanyang Technological University, Singapore*
TR706 1100 - 1130h	(A244) Revealing the complexity behind process of transformation of content knowledge Read abstract	**Elizabeth MAVHUNGA** *Wits University*
TR706 1130 - 1200h	(A386) The Factors of Pre-Service Teacher Training Process to Create Active Learning in Teaching Science: Case Study the Pre-Service Science Teachers in Thailand Read abstract	**Ruhaisa DEARAMAE** *Khon Kean University* **Jiradawan HUNTULA** *Khon Kean University*

Concurrent 2.7 (Paper) Strand: Science in Informal Settings

Venue & Time	Paper title	Authors
TR709 1030 - 1100h	(A180) Learning trajectory of science undergraduates working as interns in research laboratories Read abstract	**Cassander TAN** *National Institute of Education, Nanyang Technological University, Singapore* **Aik Ling TAN** *National Institute of Education, Nanyang Technological University, Singapore*
TR709 1100 - 1130h	(A223) Validating a Causal Model of Moral Obligation for Plant Conservation in a Nationwide Garden-based Education Program among High School Students in Thailand Read abstract	**Pongprapan PONGSOPHON** *Kasetsart University* **William MCCOMAS** *University of Arkansas*
TR709 1130 - 1200h	(A299) Eliciting student engagement in science in informal settings Read abstract	**Miguel ISON** *University of the West Indies* **Sharon BRAMWELL-LALOR** *University of the West Indies*

Day 2
20 JUNE

CONCURRENT SESSION 2

Concurrent 2.8 (Paper) Strand: History, Philosophy and Sociology

Venue & Time	Paper title	Authors
TR710 1030 - 1100h	(A282) Nature of Science in Relativity: Analysis of Korean Textbooks Read abstract	**Wonyong PARK** *Seoul National University* **Seungran YANG** *Seoul National University* **Jinwoong SONG** *Seoul National University*
TR710 1100 - 1130h	(A303) A Phenomenological Study of the Experiences of Successful Women in Science Fields Read abstract	**Jonathan HALL** *University of Central Florida* **Malcolm BUTLER** *University of Central Florida*
TR710 1130 - 1200h	(A387) Students` conceptions of the Nature of Science: A pilot study of an "Act a Scientist Test" Read abstract	**Jaakko TURKKA** *University of Helsinki* **Maija AKSELA** *University of Helsinki*

Concurrent 2.9 (Paper) Strand: Assessment and Evaluation

Venue & Time	Paper title	Authors
TR711 1030 - 1100h	(A234) Factors affecting students' interest in broad science topics Read abstract	**Derek CHEUNG** *The Chinese University of Hong Kong*
TR711 1100 - 1130h	(A275) Development and Implementation of a Conceptual Survey in RLC Series Circuits Read abstract	**Pornrat WATTANAKASIWICH** *Chiang Mai University* **Kiadtisak SRISAIKHAM** *Chiang Mai University*
TR711 1130 - 1200h	(A415) Investigating Formative Assessment Practices in Science Classrooms Read abstract	**Hye-Eun CHU** *Macquarie University* **Kim Chwee Daniel TAN** *National Institute of Education, Nanyang Technological University Singapore*

Day 2
20 JUNE

CONCURRENT SESSION 2

Concurrent 2.10 (Paper) Strand: Curriculum and Policy

Venue & Time	Paper title	Authors
TR712 1030 - 1100h	(A242) Coordinating policy reform with existing teaching practice: A longitudinal interview study of teachers' responses to national testing and grading in science education in year 6 in Sweden Read abstract	**Malena LIDAR** *Uppsala University* **Eva LUNDQVIST** *Uppsala University*
TR712 1100 - 1130h	(A311) Introductory Physics Courses at KSU and Students' Performance Tiers Read abstract	**Fahad AL-SHAYA** *King Saud University* **Maher AL-ARFAJ** *King Faisal University* **Saad AL-OMRAN** *King Saud University* **Abdu AL_MUFTI** *King Saud University*
TR712 1130 - 1200h	(A354) Nurturing Scientific Literacy for All Undergraduates via Science Classics Read abstract	**Kai Ming KIANG** *The Chinese University of Hong Kong*

Concurrent 2.11 (Workshop) Strand: Assessment and Evaluation

Venue & Time	Paper title	Authors
NIE3-B1-21 1030 - 1200h	(W172) Rasch Measurement for In-Class Science Assessments Read abstract	**Vahid ARYADOUST** *National Institute of Education, Nanyang Technological University, Singapore*

Concurrent 2.12 (Workshop) Strand: Science Teaching and Learning

Venue & Time	Paper title	Authors
TR714 1030 - 1200h	**(W423)** Crafting Literature Appreciation Task Read abstract	**Chorng Shin WEE** *Hwa Chong Institution* **Gah Hung LEE** *Hwa Chong Institution*

Day 2
20 JUNE

CONCURRENT SESSION 2

Concurrent 2.13 Marshall Cavendish Education (Exhibitor's Workshop)

Venue & Time	Paper title
TR715 1030 - 1200h	(EW004) Designing for Applied Learning in STEM Read abstract

Concurrent 2.14 Mosaic Global (Exhibitor's Workshop)

Venue & Time	Paper title
TR716 1030 - 1200h	(EW005) Gifted and Science Olympiad education Read abstract

Concurrent 2.15 Spectra-Teknik (S) Pte Ltd (Exhibitor's Workshop)

Venue & Time	Paper title
TR717 1030 - 1200h	(EW006) Science of Water Read abstract

KEYNOTE PRESENTATION 3

Venue & Time	Keynote title	Authors
LT1 1330-1430h	The Role of Argumentation Discourse in the Design of Knowledge-building Learning Experiences and Environments Read abstract	**Richard DUSCHL** *Pennsylvania State University*

Day 2
20 JUNE

CONCURRENT SESSION 3

Concurrent 3.1 (Symposium) Strand: Science Teaching and Learning

Venue & Time	Paper title	Authors
TR701 1430 - 1600h	(S305) Enhancing students' content learning through multimodal meaning-making in Primary Science Read abstract	**Discussant: Jennifer YEO** *National Institute of Education, Nanyang Technological University, Singapore*
	Symposium Paper 1 Supporting students' conceptual understanding through the use of student-created notebooks in Primary Science	**Caroline HO** *Ministry of Education, Singapore* **Noorhafidzah SHAFFI** *Ang Mo Kio Primary School* **Amy TAN** *Ang Mo Kio Primary School* **Choo Lat WONG** *Ang Mo Kio Primary School*
	Symposium Paper 2 Using of multimodal representations for differentiated instruction	**Sumathi MANICKAM** *Park View Primary School* **Yong Ngee KANG** *Park View Primary School*
	Symposium Paper 3 Supporting teachers' use of multi-modal meaning-making	**Anne WONG** *Academy of Singapore Teachers, Ministry of Education, Singapore* **Lai Har Judy LEE** *Academy of Singapore Teachers, Ministry of Education, Singapore*

Concurrent 3.2 (Paper) Strand: Science T*eaching and Learning

Venue & Time	Paper title	Authors
TR702 1430 - 1500h	(A286) Developing competencies and dispositions for the 21st century through authentic project based learning Read abstract	**Boon Hwee NG** *Temasek Junior College*
TR702 1500 - 1530h	(A326) Participation, Positioning, and Power: Opportunities to Learn in a University Kinesiology Classroom Read abstract	**Allison RITCHIE** *University of Toronto*
TR702 1530 - 1600h	(A331) Community-Based Learning in Environmental Education: Assessing Students' Reflections on Community Engagement and Environmental Knowledge Read abstract	**Carmina DALIDA** *University of Santo Tomas* **Catherine Genevieve LAGUNZAD** *Ateneo De Manila University*

Day 2

20 JUNE

CONCURRENT SESSION 3

Concurrent 3.3 (Paper) Strand: Science Teaching and Learning

Venue & Time	Paper title	Authors
TR703 1430 - 1500h	(A255) Secondary School Students' Critique of Science Research Posters Read abstract	**Yann Shiou ONG** *Pennsylvania State University* **Richard DUSCHL** *Pennsylvania State University* **Julia PLUMMER** *Pennsylvania State University*
TR703 1500 - 1530h	(A257) Teachers' Perceptions on Chemistry Laboratory and Using Green Chemistry as 21st Century Laboratory Learning in Secondary Schools Read abstract	**Mageswary KARPUDEWAN** *University Science Malaysia* **Yvonne KULANDAISAMY** *University Science Malaysia*
TR703 1530 - 1600h	(A343) Unlocking Secondary School Students' Potential for Science Through Memory Palace Read abstract	**Weicheng PUA** *Hillgrove Secondary School*

Concurrent 3.4 (Paper) Strand: Science Teaching and Learning

Venue & Time	Paper title	Authors
TR704 1430 - 1500h	(A198) Science classroom teaching in Singapore: Initial findings from the CORE 3 research program Read abstract	**Dennis KWEK** *National Institute of Education, Nanyang Technological University, Singapore* **Yew-Jin LEE** *National Institute of Education, Nanyang Technological University, Singapore* **Hwei-Ming WONG** *National Institute of Education, Nanyang Technological University, Singapore*
TR704 1500 - 1530h	(A424) Evaluating Pupil Perception in the use of Technology in a Primary Science Classroom Read abstract	**Grace QUEK** *Catholic High School (Pri)*

Day 2
20 JUNE

CONCURRENT SESSION 3

Concurrent 3.5 (Paper) Strand: Science Teaching and Learning

Venue & Time	Paper title	Authors
TR705 1430 - 1500h	(A381) An analysis of the levels of external representations about Genetics in high school students Read abstract	**Beatriz GARCIA-RIVERA** *Universidad Nacional Autónoma de México* **Leticia GALLEGOS-CÁZARES** *Universidad Nacional Autónoma de México* **Fernando FLORES-CAMACHO** *Universidad Nacional Autónoma de México* **Araceli BÁEZ-ISLAS** *Universidad Nacional Autónoma de México* **Elena CALDERON-CANALES** *Universidad Nacional Autónoma de México*
TR705 1500 - 1530h	(A379) The influence of ICT in the learning of Genetics Read abstract	**Beatriz GARCIA-RIVERA** *Universidad Nacional Autónoma de México* **Fernando FLORES-CAMACHO** *Universidad Nacional Autónoma de México* **Leticia GALLEGOS-CÁZARES** *Universidad Nacional Autónoma de México* **Elena CALDERON-CANALES** *Universidad Nacional Autónoma de México* **Araceli BÁEZ-ISLAS** *Universidad Nacional Autónoma de México*
TR705 1530 - 1600h	(A220) Learning the nature of photon and quantization energy of electron through a board game Read abstract	**Ary NORSAPUTRA** *Mahidol University* **Suchai NOPPARATJAMJOMRAS** *Mahidol University* **Ratchapak CHITTAREE** *Mahidol University* **Thasaneeya Ratanaroutai NOPPARATJAMJOMRAS** *Mahidol University*

Concurrent 3.6 (Paper)
Strand: Science Teacher Professional Development and Teacher Education

Venue & Time	Paper title	Authors
TR706 1430 - 1500h	(A246) Examining Factors Challenging Pre-Service Science Teachers' Expectations About Inclusive Science Education Read abstract	**Da Yeon KANG** *Seoul National University* **Sonya N. MARTIN** *Seoul National University*
TR706 1500 - 1530h	(A274) Main features of teacher professional development programs to promote teaching practice: A lesson learned from Portuguese and Thai context Read abstract	**Surayot SUPPRAKOB** *Phranakorn Rajabhat University* **Bernardino LOPES** *Universidade de Trás-os-Montes e Alto Douro* **Alexandre PINTO** *Polytechnic Institute of Porto* **Chatree FAIKHAMTA** *Kasetsart University* **Potjanart SUWANRUJI** *Kasetsart University*
TR706 1530 - 1600h	(A399) Investigating pre-service science teacher's ability to notice student thinking Read abstract	**Sze Him LAM** *University of Cambridge* **Kam Ho CHAN** *The University of Hong Kong*

Day 2
20 JUNE

CONCURRENT SESSION 3

Concurrent 3.7 (Paper)
Strand: Science in Informal Settings | Strand: Science Teaching and Learning

Venue & Time	Paper title	Authors
TR709 1430 - 1500h	(A340) Relooking environmental science education: the pedagogical value of community-based research projects in higher education Read abstract	**Tai Chong TOH** *National University of Singapore* **Siok Kuan TAMBYAH** *National University of Singapore*
TR709 1500 - 1530h	(A420) How science textbooks could affect students learning in informal learning environments Read abstract	**Fatema ALAMOURI** *University of Reading*

Concurrent 3.8 (Paper) Strand: History, Philosophy and Sociology

Venue & Time	Paper title	Authors
TR710 1430 - 1500h	(A182) Subcultures of lower track science classrooms: An analysis of power relationships Read abstract	**Tang Wee TEO** *National Institute of Education, Nanyang Technological University, Singapore*
TR710 1500 - 1530h	(A300) The changing conception of science education curricula in historical US reform movements Read abstract	**Steve J. OLIVER** *University of Georgia*
TR710 1530 - 1600h	(A400) Exploring Thai Students' Social Equity Perspective through Socioscientific Issues Read abstract	**Chanathip JANSONG** *Kasetsart University* **Sasithep PITIPORNTAPIN** *Kasetsart University* **Pramote CHAUMNANPUEN** *Kasetsart University*

Concurrent 3.9 (Paper)
Strand: Curriculum and Policy | Strand: Science in Informal Settings

Venue & Time	Paper title	Authors
TR711 1430 - 1500h	(A222) A Policy Ethnographic Approach to Examining the Implementation of Environmental Education Policy in Taiwan Read abstract	**Ying-Syuan HUANG** *McGill University*
TR711 1500 - 1530h	(A319) Science Curriculum Reforms and its Effects on Classroom Practices: A Case of some Selected Basic schools in Ghana Read abstract	**Charles Deodat OTAMI** *University of Cape Coast*
TR711 1530 - 1600h	(A217) The effect of a camp-based science methods course on pre-service teachers' self-efficacy in teaching science as inquiry Read abstract	**Elsun SEUNG** *Indiana State University* **Soonhye PARK** *North Carolina State University* **Myung-Ah LEE** *Indiana State University*

Day 2
20 JUNE

CONCURRENT SESSION 3

Concurrent 3.10 (Workshop) Strand: Science Teaching and Learning

Venue & Time	Paper title	Authors
TR712 1430 - 1600h	(W383) Lower Seletar Reservoir Trail Read abstract	**Huazhi CHAN** *Christ Church Secondary School* **Sabrina JUMANDI** *Christ Church Secondary School*

Concurrent 3.11 (Workshop) Strand: Science Teaching and Learning

Venue & Time	Paper title	Authors
TR713 1430 - 1600h	(W241) Inquiry in Science: Fun With Toys Read abstract	**Su Sze KONG** *Queenstown Primary School* **Soon Shan TAN** *Queenstown Primary School* **Lay See LIM** *Queenstown Primary School* **Yen Peng TAN** *Queenstown Primary School*

Concurrent 3.12 (Symposium)
Strand: Science Teacher Professional Development and Teacher Education

Venue & Time	Paper title	Authors
TR714 1430 - 1600h	(S240) Establishing and realising a vision for PCK research in science education Read abstract	
	Symposium Paper 1 The second PCK summit: process, models and more	**Jan van DRIEL** *The University of Melbourne* **Rebecca COOPER** *Monash University*
	Symposium Paper 2 Literature review of methodologies used for investigating individual science teachers' pedagogical content knowledge	**Kennedy CHAN** *The University of Hong Kong* **Anne HUME** *University of Waikato*
	Symposium Paper 3 Representing the complexity of PCK in action	**Amanda BERRY** *Monash University* **Alicia ALONZO** *Michigan State University* **Pernilla NILSSON** *Halmstad University*

Day 2
20 JUNE

CONCURRENT SESSION 3

Concurrent 3.13 Edukinect (Exhibitor's Workshop)

Venue & Time	Paper title
TR715 1430-1600h	(EW007) Creating 3D Content for Science Read abstract

Concurrent 3.14 Genetron Engineering Corporation Pte Ltd (Exhibitor's Workshop)

Venue & Time	Paper title
NIE7A-B1-03 1430-1600h	(EW008) Think Technology, Think Science Read abstract

Concurrent 3.15 VedicLink (Exhibitor's Workshop)

Venue & Time	Paper title
TR716 1430-1600h	(EW009) Reimagined Blended Learning Read abstract

Day 3

21 JUNE

KEYNOTE PRESENTATION 4

Venue & Time	Keynote title	Authors
LT1 0930-1030h	Students' Learning in the Sciences Read abstract	**Subramaniam RAMANATHAN** *National Institute of Education, Nanyang Technological University, Singapore*

MEET-THE-EDITORS SESSION

Venue & Time	Book
TR701 1030-1115h	Publishing in ISEC book **Book Editors:** Tang Wee TEO, Aik Ling TAN, Yann Shiou ONG *National Institute of Education, Nanyang Technological University, Singapore*
TR701 *1115-1200*	Asia-Pacific Science Education Journal **Journal Editorial Team:** Sonya N. MARTIN, Nam-Hwa KANG, Hye-Eun CHU, Da Yeon KANG

Day 3
21 JUNE

POSTER PRESENTATIONS

Time: 1030 - 1200h
Venue: Science Education Laboratory 1 (NIE7-02-01)

Poster ID	Title, Author and Institution Affiliations
P185 Read abstract	**Assessment literacy of science teachers across levels** Rizalina ANDAMO, *Philippine Normal University*
P189 Read abstract	**Does seeing mean learning? A qualitative study of multimedia design (MMD) principles and molecular representation using eye tracking and verbal protocols** Poh Nguk LAU, *Temasek Polytechnic, Singapore & Columbia University*
P191 Read abstract	**An Attempt to Theorize the Lesson Study: Focusing on Teachers' Knowledge** Tetsuo ISOZAKI, *Hiroshima University* Takako ISOZAKI, *The University of Toyama*
P200 Read abstract	**Is the teaching approach of peer-review an effective tool for improving laboratory report-writing skills for Stage2 Biomedical Science students at Newcastle University Medicine Malaysia (NUMed)?** Pamela Anne KNIGHT, *Newcastle University Medicine Malaysia*
P233 Read abstract	**Re-conceptualizing Scientific Literacy in the Context of Urban Farming** Gyeong Mi GI, *Seoul National University* Sonya N. MARTIN, *Seoul National University* Saerom AHN, *Seoul National University*
P243 Read abstract	**Effects of Teaching Practices on Students' Academic Performance in Science** Marcelino IBANEZ, *Division of Masbate, Department of Education, Philippines* Mark Anthony RUPA, *Division of Masbate, Department of Education, Philippines*
P248 Read abstract	**Suggestions for Virtual Learning Contents based on a Case Study of Augmented Reality Content in Korea's 2015 Secondary Science Curriculum Digital Textbook** Sonya N. MARTIN, *Seoul National University* Ki Eun EOM, *Seoul National University*
P264 Read abstract	**Constructively aligned teaching sequence (CATS): A tool for teaching organismal biology in STEM senior high school education** Joyce MAGTOLIS, *Leyte Normal University* Antonio BATOMALAQUE, *University of San Carlos*
P283 Read abstract	**Analysis of Physical and Science Education interdisciplinary lesson plans in US Elementary Schools** Myung-Ah LEE, *Indiana State University* Elsun SEUNG, *Indiana State University*
P287 Read abstract	**Development of Game-based Science Simulation for Promoting Elementary School Students' Learning in Plant Growth** Daranee JAIMEETAM, *Khon Kaen University* Niwat SRISAWASDI, *Khon Kaen University*
P293 Read abstract	**Enhancing Grade 11 Students' Scientific Conceptions of Animal Classification Using Inductive Inquiry** Thitaporn INNGAM, *Khon Kaen University* Parichat SAENNA, *Khon Kaen University*
P294 Read abstract	**Smartphone-based Chemistry Laboratory Lessons for Promoting Middle School Students' Perception and Attitude in Chemistry Learning** Banjong PRASONGSAP, *Khon Kaen University* Niwat SRISAWASDI, *Khon Kaen University*

Poster ID	Title, Author and Institution Affiliations
P295 Read abstract	**To Eliminate Students' Misconceptions of Heat Transfer: A Development of Interactive Simulation regarding DSLM Approach** Sureerat SATCHUKORN, *Khon Kaen University* Niwat SRISAWASDI, *Khon Kaen University*
P312 Read abstract	**Case-based and experiential learning: Engaging pharmaceutical sciences students in pharmacotherapy** Wei Xiu SUNG, *Nanyang Polytechnic*
P321 Read abstract	**Trends of students' performance in senior school certificate biology examinations (2007-2016) in Ondo Central Senatorial District, Nigeria** Mulkah Adebisi AHMED, *University of Ilorin* Lukman YAHAYA, *University of Ilorin* Abiodun Ademolu FAGBOLA, *University of Ilorin*
P324 Read abstract	**Students' perceptions on inquiry-based learning for organic chemistry laboratory** Pek-Ling LYE, *Nanyang Polytechnic* Jayden ANG, *Nanyang Polytechnic*
P328 Read abstract	**Roles of and Interactions among Students with Different Cognitive Preference in Playing an Ecology Table Game** Chun-yi CHENG, *National Taiwan Normal University* Wen-Hua CHANG, *National Taiwan Normal University*
P341 Read abstract	**Estimation of the Value of Environmental Education in Science Museum by a Conjoint Analysis** Akihiro IIJIMA, *Takasaki City University of Economics* Rina NAGASHIMA, *Takasaki City University of Economics* Mamoru CHACHIN, *Gunma Insect World*
P346 Read abstract	**The study of students' understanding in nature of science** Kamonlapat PUENGPAN, *Mahasarakham University* Kanyarat SONSUPAP, *Mahasarakham University* Kanyarat COJON, *Mahasarakham University* Somsong SITTI, *Mahasarakham University*
P347 Read abstract	**The study of students' achievement motivation in Physics** Peeradon ONSEE, *Mahasarakham University* Kanyarat COJORN, *Mahasarakham University* Kanyarat SORNSUPAP, *Mahasarakham University* Somsong SITTI, *Mahasarakham University*
P359 Read abstract	**The Research on Learning Progressions of Chemistry Change by ChemQuery Assessment System** Ying SUN, *Anhui Normal University* Hualin BI, *Shandong Normal University*
P364 Read abstract	**A cross-curricular study of fish anatomy and cooking** Taichiro GOTO, *Mie University* Eimi NAKAMICHI, *Mie University* Masachika KUNO, *Mie University* Yuka ISOBE, *Mie University*
P372 Read abstract	**Scientific Mental Representation of Cell Division in 10 Graders Using Multiple Representations** Siraprapha THONGPON, *Khon Kaen University* Parichat SAENNA, *Khon Kaen University*
P373 Read abstract	**Using a visual tool in improving high school students' conceptual understandings and self-generation of analogies in acid-base chemistry** Suttida THAMMAWIPAK, *Khon Kaen University* Romklao JANTRASEE, *Khon Kaen University*
P374 Read abstract	**Implementing Model-Centered Instruction Sequence to Improve High School Students' Creation of Models and Modeling Practices** Nutnaree KANAMUANG, *Khon Kaen University* Romklao JANTRASEE, *Khon Kaen University*
P375 Read abstract	**Grade 11 students' Mental Representations of Photosynthesis Using Multimedia-Embedded-Learning Sheet** Sarunthorn INTHASIRI, *Khon Kaen University* Parichat SAENNA, *Khon Kaen University*
P377 Read abstract	**Getting students involved with small-scale experiments of inquiry based approach in chemistry classroom for improving conceptual understanding** Chutika SRISAWAT, *Khon Kaen University* Romklao JANTRASEEJ, *Khon Kaen University*

Poster ID	Title, Author and Institution Affiliations
P378 Read abstract	**A Study of Grade 11 students' Analytical Thinking Ability and Learning Achievement in the Subject of "Endocrine System" through Learning Activities Based on the Science, Technology and Social (STS) Approach** Ronnasit PRADUBSRI, *Khon Kaen University* Phairoth TERMTACHATIPONGSA, *Khon Kaen University*
P385 Read abstract	**Building an Effective Assessment to Test the Applications of Physics Concepts in Higher Order Thinking Questions** Bernard RICARDO, *NUS High School of Mathematics and Science* Andre JUSUF, *NUS High School of Mathematics and Science* Choon Keat Paul LEE, *National Institute of Education,* Nanyang Technological University, *Singapore*
P401 Read abstract	**Exploring Korean School Principals' Beliefs for Teaching Diverse Students in Inclusive Classrooms** Eunhee CHA, *Seoul National University* Doo-Sung LEE, *Seoul National University* Sonya N. MARTIN, *Seoul National University*
P403 Read abstract	**Non-formal science education: The relevance of study visits to a Chemistry lab** Pipsa BLOMGREN, *University of Helsinki* Johannes PERNAA, *University of Helsinki* Maija AKSELA, *University of Helsinki*
P404 Read abstract	**Non-formal learning environments promoting teacher identity of science teacher students: Science clubs as a learning environment** Julia HALONEN, *University of Helsinki* Johannes PERNAA, *University of Helsinki* Maija AKSELA, *University of Helsinki*
P405 Read abstract	**Teaching Science through its History – The Use of Classical Experiments to Teach Science Concepts and Nature of Science** Chee Wan TAN, *Singapore Chinese Girls' School* Xuehui Arlene PANG, *Singapore Chinese Girls' School*
P408 Read abstract	**Development and Use of the Case-Based Reasoning Model of Instructional Design on Climate Change Unit** Hyoungbum KIM, *Chungbuk National University*
P414 Read abstract	**Striving for Outcome Based Education through Teacher Professional Development: a Case Study of Chemistry Undergraduate Laboratory Teaching** Chantima PATTAMATHAMMAKUL, *King Mongkut's University of Technology Thonburi* Chanen MUNKONG, *King Mongkut's University of Technology Thonburi* Sailom SAMPANVEJSOPHA, *King Mongkut's University of Technology Thonburi*
P421 Read abstract	**Making pre-service science teacher education more relevant: Integrated and project-based course collaboration between university and upper secondary school** Outi HAATAINEN, *University of Helsinki* Topias IKÄVALKO, *University of Helsinki* Maija AKSELA, *University of Helsinki*
P425 Read abstract	**Strengthening of Experimental Skills through Understanding of Rationale** Thomas LEE, *Yuan Ching Secondary School*
P426 Read abstract	**Effective use of Google Documents in collaborative learning during a Scientific Thinking** Ying Yang TAN, *Yuan Ching Secondary School* Jiawen ZHANG, *Yuan Ching Secondary School*
P427 Read abstract	**Teachers' Pedagogical Content Knowledge and Design Capacity for Scientific Explanation** Elisa IZQUIERDO-ACEBES, *University of Cambridge* *Keith S. TABER*, *University of Cambridge*
P428 Read abstract	**What are the perspectives of (a) Primary 3 students and (b) science teachers on the relationship between play and the learning of Primary Science in Singapore?** Woei Yng TAN, *University of York*

Day 3
21 JUNE

CONCURRENT SESSION 4

Concurrent 4.1 (Paper) Strand: Science Teaching and Learning

Venue & Time	Paper title	Authors
TR701 1300 - 1330h	(A216) Exploring Grade 10th Students' Deductive and Inductive Scientific Reasoning in Biology Read abstract	**Nalinee SONCHA** *Kasetsart University* **Mesayamas KONGSEMA** *Kasetsart University* **Jeerawan KETSING** *Kasetsart University*
TR701 1330 -1400h	(A412) Misconceptions of diffusion and osmosis in biology undergraduates Read abstract	**Jessica TAN** *National Institute of Education, Nanyang Technological University, Singapore* **Shit Fun CHEW** *National Institute of Education, Nanyang Technological University, Singapore*

Concurrent 4.2 (Paper) Strand: Science Teaching and Learning

Venue & Time	Paper title	Authors
TR702 1300 - 1330h	(A344) Design and Evaluation of STEM Tasks Related to Biology Read abstract	**Dominic KOH** *National Institute of Education, Nanyang Technological University, Singapore* **Aik Ling TAN** *National Institute of Education, Nanyang Technological University, Singapore*
TR702 1330 -1400h	(A370) Developing Grade 9 Students' Creativity and Innovation Skills for the 21st Century Using STEM Education in Biology Subject Read abstract	**Chalongwoot JANHOM** *Kasetsart University* **Chulaporn TONGSRINUT** *Horwang School* **Jeerawan KETSING** *Kasetsart University*

Day 3
21 JUNE

CONCURRENT SESSION 4

Concurrent 4.3 (Paper) Strand: Science Teaching and Learning

Venue & Time	Paper title	Authors
TR703 1300 - 1330h	(A176) Effectiveness of Differentiated Instruction on Students' Learning of Chemistry Concepts Read abstract	**Shyh Yuan Don YEO** *NUS High School of Math and Science* **Chong Lee Jason TAN** *Raffles Institution* **Tuck Chuen Stephen LOW** *Punggol Secondary School* **Kheam Soon Alex LIM** *CHIJ Katong Convent* **Pui San TAN** *Swiss Cottage Secondary School*
TR703 1330 - 1400h	(A249) Teaching science without words: A case study involving slow learners in Mauritius Read abstract	**Mohun CYPARSADE** *Mauritius Institute of Education*
TR703 1400 - 1430h	(A317) Effects of concept mapping technique and gender on Nigerian junior secondary school students' cognitive development and achievement in basic science Read abstract	**Bernadette OZOJI** *University of Jos*

Concurrent 4.4 (Paper) Strand: Science Teaching and Learning

Venue & Time	Paper title	Authors
TR704 1300 - 1330h	(A187) Test anxiety, science and academic performances in senior high school students Read abstract	**Rizalina ANDAMO** *Malinta National High School*
TR704 1330 - 1400h	(A245) High School Students' Conceptions on Cell Division: The Development of Student's Conceptions through Model-based Learning Integrated with Creating Multimedia Read abstract	**Virayuth KHAMDI** *Kasetsart University* **Chittamas SUKSAWANG** *Kasetsart University* **Teerasak E-KOBON** *Kasetsart University*
TR704 1400 - 1430h	(A392) Working Memory Capacity of Malaysian Form Four Science Stream Students Read abstract	**Fui Seng CHANG** *Universiti Sains Malaysia* **Mageswary KARPUDEWAN** *Universiti Sains Malaysia* **Zalina ISMAIL** *Universiti Sains Malaysia*

Day 3
21 JUNE

CONCURRENT SESSION 4

Concurrent 4.5 (Paper) Strand: Science Teaching and Learning

Venue & Time	Paper title	Authors
TR705 1300 - 1330h	(A204) Assessment on the conceptual learning in elementary school electrical activities via manufacturing scientific toys Read abstract	**Jian Yi LIN** *National Taipei University of Education* **Ching-san LAI** *National Taipei University of Education*
TR705 1330 - 1400h	(A261) A case study exploring science teachers' journey into the pedagogical design and practices of authentic assessments at lower secondary level Read abstract	**Josephine CHANG** St. Joseph's Institution **Jerry TAI** St. Joseph's Institution **Kah Yan WONG** St. Joseph's Institution **Jun Hien CHONG,** St. Joseph's Institution
TR705 1400 - 1430h	(A272) Types of practical examination in chemistry laboratory and their effects on students' achievement: basis for instructional guidelines development Read abstract	**Maria Fatima GUMAPAC** *De La Salle Lipa, Inc.*

Concurrent 4.6 (Paper) Strand: Science Teaching and Learning

Venue & Time	Paper title	Authors
TR706 1300 - 1330h	(A207) Guided Inquiry Approach: Effects on the Development of Conceptual Understanding, Process Skills, Critical Thinking and Attitudes in High School Chemistry Read abstract	**Mark Anthony RUPA** *Division of Masbate, Department of Education, Philippines*
TR706 1330 - 1400h	(A365) Epistemic Approaches to Problem-solving in Design-based Inquiry Activities Read abstract	**Timothy Ter Ming TAI** *National Institute of Education, Nanyang Technological University, Singapore* **Yew-Jin LEE** *National Institute of Education, Nanyang Technological University, Singapore*
TR706 1400 - 1430h	(A391) Student-question-based inquiry in science education Read abstract	**Jaana HERRANEN** *University of Helsinki* **Maija AKSELA** *University of Helsinki*

Day 3
21 JUNE

CONCURRENT SESSION 4

Concurrent 4.7 (Paper) Strand: Science Teaching and Learning

Venue & Time	Paper title	Authors
TR709 1300 - 1330h	(A218) Research on Science Teaching Improvement in the Post-PISA Era ——Focuses on " Explain the Phenomenon Scientifically " in Aqueous Solution Theme Read abstract	**Chuan LI** *Beijing Normal University* **Lei WANG** *Beijing Normal University*
TR709 1330 - 1400h	(A247) The Effect of Argument-Driven Inquiry on High School Students' Scientific Argumentation Read abstract	**Wilaiwan SONGSIL** *Kasetsart University* **Pongprapan PONGSOPHON** *Kasetsart University* **Boonsatien BOONSOONG** *Kasetsart University*
TR709 1400 - 1430h	(A320) Enhancing Students' Science Process Skills and Metacognitive Awareness Through Guided Inquiry Laboratory Activities (GILA) Read abstract	**Jellina ROSGA** *Cavite National High School*

Concurrent 4.8 (Paper)
Strand: Science Teacher Professional Development and Teacher Education

Venue & Time	Paper title	Authors
TR710 1300 - 1330h	(A298) Pre-service Science Teachers' Conceptions of Teaching: Reflections on the Field Experience Read abstract	**Sharon BRAMWELL-LALOR** *University of the West Indies* **Marcia RAINFORD** *University of the West Indies* **Miguel ISON** *University of the West Indies*
TR710 1330 - 1400h	(A384) A comparative case study of the implementation of active learning resources in four different socio-political contexts: The United States, Chile, Mexico and Colombia Read abstract	**Marjee CHMIEL** *Howard Hughes Medical Institute* **Rodrigo TAPIA** *Biomedical Neuroscience Institute* **Javier ROBALINO** *Howard Hughes Medical Institute* **Gonzalo PEÑALOZA** *Maloka Science Centre, Bogotá*

Day 3
21 JUNE

CONCURRENT SESSION 4

Concurrent 4.9 (Symposium)
Strand: Assessment and Evaluation | Strand: Science for the Early Years

Venue & Time	Paper title	Authors
TR711 1300 - 1330h	(A174) How Presenters' Likeability Affects Peer Assessments of their Presentation Skills: A Study of Singaporean Science Students Read abstract	**Vahid ARYADOUST** *National Institute of Education, Nanyang Technological University, Singapore*
TR711 1330 - 1400h	(A289) Two-tier Test to Investigate Students' Difficulties in Indicating a Direction of DC Current by Ammeter Read abstract	**Suchai NOPPARATJAMJOMRAS** *Mahidol University* **Thasaneeya Ratanaroutai NOPPARATJAMJOMRAS** *Mahidol University*
TR711 1400 - 1430h	(A366) The Use of Science Notebooks for Science Activities in Preschool Education Read abstract	**Elena CALDERÓN-CANALES** *Universidad Nacional Autónoma de México* **Leticia GALLEGOS-CÁZARES** *Universidad Nacional Autónoma de México* **Fernando FLORES-CAMACHO** *Universidad Nacional Autónoma de México*

Concurrent 4.10 (Workshop) Strand: Science Teaching and Learning

Venue & Time	Paper title	Authors
TR712 1300 - 1430h	(W184) A Modelling Approach to the Teaching of Chemistry using Whiteboarding Read abstract	**Li Kheang KOO** *Cedar Girls' Secondary School* **Yan Li TAN** *Victoria School* **Julianah JOHAR** *Jurong Secondary School*

Day 3
21 JUNE

CONCURRENT SESSION 4

Concurrent 4.11 (Paper)
Strand: Science Teacher Professional Development and Teacher Education

Venue & Time	Paper title	Authors
TR713 1300 - 1430h	(S263) Teaching and learning science through the language lens (Part 1) Read abstract	**Discussant: Aik Ling TAN** *National Institute of Education, Nanyang Technological University, Singapore*
	Symposium Paper 1 Adopting Teacher Language Awareness as a lens to inform a professional development inquiry process to infuse language support for science learning	**Lay Hoon SEAH** *National Institute of Education, Nanyang Technological University, Singapore* **Jonathon ADAMS** *Ministry of Education, Singapore*
	Symposium Paper 2 Developing Science Literacy in primary classrooms	**Azlinda ABD AZIZ** *Pioneer Primary School*
	Symposium Paper 3 Investigating the use of word cards in the teaching of Science	**Nurhuda AMIN** *West Grove Primary School*

Day 3
21 JUNE

CONCURRENT SESSION 4

Concurrent 4.12 (Seminar) Modality in Science Education Seminar (Theory Section)

Venue: TR715
1030-1300h
Open for first 15 registrants from only

Chair persons:
Jennifer YEO
National Institute of Education, Nanyang Technological University, Singapore
Wendy NIELSEN
University of Wollongong

Paper title	Authors
The Concept of Affordance in Teaching and Learning Undergraduate Science Read abstract	**John AIREY** *Uppsala University & Stockholm University*
Keeping the Main Thing the Main Thing in Traversing Multimodal Meaning-making in Science Read abstract	**Caroline HO** *Ministry of Education, Singapore*
The Construction of Meaning through Image-Language Interaction in Static Visualizations in School Science Read abstract	**Len UNSWORTH** *Australian Catholic University*
A Framework of Scientific Explanation, Using Halliday's Model of Language as an Organising Structure Read abstract	**Jennifer YEO** *National Institute of Education, Nanyang Technological University, Singapore* **John GILBERT** *The University of Reading*
How Far can Multimodal Teaching Go in Science Teaching? Read abstract	**Maurice CHENG** *The University of Hong Kong* **Kristina DANIELSSON** *Stockholm University* **Yuen Yi LO** *The University of Hong Kong* **M. Y. Angel LIN** *Simon Fraser University*
Theoretical Perspectives on Learning When Students Create Multimodal Digital Explanations Read abstract	**Wendy NIELSEN** *University of Wollongong* **Helen GEORGIOU** *University of Wollongong* **Pauline JONES** *University of Wollongong* **Annette TURNEY** *University of Wollongong*
Reasoning in Science Through Representing Across Modes Read abstract	**Russell TYTLER** *Deakin University* **Vaughan PRAIN** *Deakin University*

Concurrent 4.13 Expenovate Pte Ltd (Exhibitor's Workshop)

Venue & Time	Paper title
TR714 1300 - 1430h	(EW010) STEM does not mean scary coding!! - Introducing fun and non-intimidating STEM for lower primary students, without the nightmare for the teachers Read abstract

Day 3
21 JUNE

CONCURRENT SESSION 5

Concurrent 5.1 (Paper) Strand: Science Teaching and Learning

Venue & Time	Paper title	Authors
TR701 1500 - 1530h	(A230) The Co-Construction of Scientific Mental Model (CCSM) in Molecular Genetics Unit among High School Students Read abstract	**Warithar RATTANAPANJAK** *Kasetsart University* **Pongprapan PONGSOPHON** *Kasetsart University* **Teerasak E-KOBON** *Kasetsart University*
TR701 1530 - 1600h	(A236) Factors Influencing High School Students' Ethical Reasoning on the Application of Modern Biotechnology Read abstract	**Onrumpa KUMNUANEK** *Kasetsart University* **Pongprapan PONGSOPHON** *Kasetsart University* **Uraiwan ARUNYAWAT** *Kasetsart University*
TR701 1600 - 1630h	(A238) Socio-Scientific Issues in Indonesia Science Teaching Read abstract	**Faisal SUDRAJAT** *Seoul National University* **Sonya N. MARTIN** *Seoul National University*

Concurrent 5.2 (Paper) Strand: Science Teaching and Learning

Venue & Time	Paper title	Authors
TR702 1500 - 1530h	(A239) Using Interest-Based Learning to Motivate Disinterested Students in the Learning of Secondary School Physics Read abstract	**Kam Kheun HONG** *Changkat Changi Secondary School* **Shi Ru NG** *Changkat Changi Secondary School*
TR702 1530 - 1600h	(A253) Effectiveness of Intellectual Standards to Develop Critical Thinking Skills in Sec 3 Chemistry Students Read abstract	**Kian Seh LOW,** *Temasek Junior College* **Zhe Ming Shawn NEO** *Temasek Junior College* **Yuan Shun HO** *Temasek Junior College* **Miaohui TNG** *Temasek Junior College* **Xuanjun LI** *Temasek Junior College*
TR702 1600 - 1630h	(A382) 'Visible Thinking' Routines for the Synthesis of Concepts in Science Read abstract	**Umay KHNG** *Raffles Girls' School (Secondary)* **Kian Hong YANG** *Raffles Girls' School (Secondary)*

Day 3
21 JUNE

CONCURRENT SESSION 5

Concurrent 5.3 (Paper) Strand: Science Teaching and Learning

Venue & Time	Paper title	Authors
TR703 1500 - 1530h	(A337) Flipped Classroom in Teaching Biology: Its Implications on Student-Centered Instruction and Students' Academic Performance Read abstract	**Gladys Ann MALTO** *The National Teachers College* **Catherine Genevieve LAGUNZAD** *Ateneo De Manila University*
TR703 1530 - 1600h	(A352) Examining the positionalities of a teacher teaching in lower track science classrooms Read abstract	**Meixue Michelle ONG** *Serangoon Secondary School* **Tang Wee TEO** *National Institute of Education, Nanyang Technological University, Singapore*

Concurrent 5.4 (Paper) Strand: Science Teaching and Learning

Venue & Time	Paper title	Authors
TR704 1500 - 1530h	(A186) Factors affecting chemistry achievement and academic performance among freshman nursing students Read abstract	**Rizalina ANDAMO** *Philippine Normal University*
TR704 1530 - 1600h	(A267) The mental model about celestial sphere of 4th year science student teachers Read abstract	**Paniwad SENKED** *Khon Kaen University* **Jiradawan HUNTULA** *Khon Kaen University*

Concurrent 5.5 (Paper) Strand: Science Teaching and Learning

Venue & Time	Paper title	Authors
TR705 1500 - 1530h	(A281) Enhancing Eleventh Graders Mental Models of Solids, Liquids and Gases through Model-based Learning with Argumentations Read abstract	**Warapa SUSINGRAT** *Kasetsart University* **Chatree FAIKAMTA** *Kasetsart University* **Surasinee KITYAKARN** *Kasetsart University*
TR705 1530 - 1600h	(A284) Interactive Lecture Demonstration and Inquiry-Based Instruction in Addressing Students' Misconceptions in Electric Circuits Read abstract	**Mark Anthony CASIMIRO** *Marikina Science High School* **Ivan CULABA** *Ateneo De Manila University*
TR705 1600 - 1630h	(A250) Teaching and learning of 'Dynamics' through a socio-constructivist approach: a case study of conceptual change at O-Level Read abstract	**Mohun CYPARSADE** *Mauritius Institute of Education*

Day 3
21 JUNE

CONCURRENT SESSION 5

Concurrent 5.6 (Paper) Strand: Science Teaching and Learning

Venue & Time	Paper title	Authors
TR706 1500 - 1530h	(A192) Development of Metacognitive-Enhanced Learning Resource Materials in Molecular Genetics: Effects on Students' Metacognition and Classroom Environment Read abstract	**Richard Deanne SAGUN** *Ateneo de Manila Junior High School* **Maricar S. PRUDENTE** *De La Salle University*
TR706 1530 - 1600h	(A271) Alternative lens for student's response about chemical bonding Read abstract	**Patcharaporn ONTHONG** *Kasetsart University* **Akarat TANAK** *Kasetsart University* **Wanchai PLUEMPANUPAT** *Kasetsart University*
TR706 1600 - 1630h	(A226) Development of Context-Based Laboratory Activities in Chemical Reactions Using Low-Cost Laboratory Kit Read abstract	**Rona Lynne ABENOJA-FEDERIZO** *The National Teachers College* **Valera NESTOR** *Ateneo de Manila University*

Concurrent 5.7 (Paper) Strand: Science Teaching and Learning

Venue & Time	Paper title	Authors
TR709 1500 - 1530h	(A388) Generating of Scientific Explanation: The Effects of Generate an argument instructional model on Newton' Laws Classroom Read abstract	**Saksit HEMKAEW** *Demonstration School of Ramkhamhaeng University* **Pannida MEELA** *Demonstration School of Ramkhamhaeng University*
TR709 1530 - 1600h	(A390) Psycho-socio and biographical variables: scientific aptitude and secondary school students Read abstract	**Dayal PYARI** *Amity Institute of Education*
TR709 1600 - 1630h	(A318) Effects of V-Mapping strategy on Nigerian junior secondary school students' test-anxiety and achievement in basic science and technology Read abstract	**Bernadette OZOJI** *University of Jos*

Day 3

21 JUNE

CONCURRENT SESSION 5

Concurrent 5.8 (Paper) Strand: New Media and Technologies

Venue & Time	Paper title	Authors
TR710 1500 - 1530h	(A203) Examining the Pedagogy of Problem Solving and Critical thinking Using A New Lens - Geographic Information Systems Read abstract	**Josephine DESOUZA** *Ball State University*
TR710 1530 - 1600h	(A329) A Multi-Case Study on Teaching Practices and How Teachers Use Technology to Support Scientific Inquiry in 1:1 Classrooms Read abstract	**Nel VENZON** *University of Southern California*
TR710 1600 - 1630h	(A251) Children's critical literacy skills on scientific environmental problem solving Read abstract	**Mijung KIM** University of Alberta **Suzanna WONG** University of Alberta

Concurrent 5.9 (Paper)
Strand: Science Teacher Professional Development and Teacher Education

Venue & Time	Paper title	Authors
TR711 1500 - 1530h	(A278) Designing Professional Development for In-service Science Teachers through Assessing Chemistry Content Knowledge Read abstract	**Yna Camille MONGCAL** *Philippine Science High School - Main Campus* **Armando GUIDOTE JR** *Ateneo de Manila University* **Queena LEE-CHUA** *Ateneo de Manila University*
TR711 1530 - 1600h	(A363) How a beginning science teacher deal with practical work: An explorative study through the lens of identity Read abstract	**Bing WEI** *University of Macau*
TR711 1600 - 1630h	(A398) Effectiveness of Activity-Based Instruction (ABI) and Interactive Lecture Demonstration (ILD) in addressing misconceptions in geometric optics Read abstract	**Sherryl PONTILLAS** *Ateneo de Manila University* **Ivan CULABA** *Ateneo de Manila University*

Day 3
21 JUNE

CONCURRENT SESSION 5

Concurrent 5.10 (Workshop) Strand: Science Teaching and Learning

Venue & Time	Paper title	Authors
TR712 1500 - 1630h	(W361) Game-based Learning for Chemistry Topics: Atomic Structure and Chemical Bonding Read abstract	**Mea Fun CHONG** *Christ Church Secondary School* **Yun Yan Lynn TANG** *Christ Church Secondary School* **Qing Cong Eugene TEO** *Christ Church Secondary School*

Concurrent 5.11 (Symposium)
Strand: Science Teacher Professional Development and Teacher Education

Venue & Time	Paper title	Authors
TR713 1500 - 1630h	(S266) Teaching and learning science through the language lens (Part 2) Read abstract	**Discussant: Aik Ling TAN** *National Institute of Education, Nanyang Technological University, Singapore*
	Symposium Paper 1 Support for helping secondary school students in constructing logical and concise writings in Science	**Swee Leng YEO-TAN** *Ping Yi Secondary School*
	Symposium Paper 2 The role of classroom discourse in promoting students' competency in language use in science	**Lay Hoon SEAH** *National Institute of Education, Nanyang Technological University, Singapore* **Pavithra RAJA** *National Institute of Education, Nanyang Technological University, Singapore* **Zhao Xiong LIM** *National Institute of Education, Nanyang Technological University, Singapore*

Day 3
21 JUNE

CONCURRENT SESSION 5

Concurrent 5.12 (Seminar)
Strand: Modality in Science Education Seminar (Practice Section)

Venue: TR715
1430 - 1630h
Open for first 15 registrants only

Chairpersons:
Jennifer YEO
National Institute of Education, Nanyang Technological University, Singapore
Wendy NIELSEN
University of Wollongong

Paper title	Authors
An Image-to-Writing Approach to Primary Science Learning: Enactment and Challenges Read abstract	**Jennifer YEO** *National Institute of Education, Nanyang Technological University, Singapore* **Wai Lit WONG** *National Institute of Education, Nanyang Technological University, Singapore* **Kim Chwee Daniel TAN** *National Institute of Education, Nanyang Technological University, Singapore* **Aloysius ONG** *National Institute of Education, Nanyang Technological University, Singapore* **Eugene LIM** *National Institute of Education, Nanyang Technological University, Singapore* **Poh Hiang TAN** *Academy of Singapore Teachers, Ministry of Education, Singapore*
Representation Construction: A Research Developed Guided Inquiry Pedagogy for Science Education Read abstract	**Peter HUBBER** *Deakin University*
Learning in STEM through Constructing, Evaluating and Orchestrating Representational Systems Read abstract	**Russell TYTLER** *Deakin University* **Peta WHITE** *Deakin University*
Examining the Communicative Potential of Visual Representations to Learn Science Read abstract	**Jonathan ADAMS** *Ministry of Education, Singapore*
Multimodal Transduction in Upper-secondary School Physics Read abstract	**Trevor VOLKWYN** *University of the Western Cape & Uppsala University* **John AIREY** *University of the Western Cape & Stockholm University* **Bor GREGORČIČ** *Uppsala University* **Filip HEIJKENSKJÖLD** *Uppsala University*
Visualizations in matriculation level science examinations: Mapping the nature and extent of image creation required in student responses. Read abstract	**Len UNSWORTH** *Australian Catholic University*

Day 3

21 JUNE

CONCURRENT SESSION 5

Concurrent 5.13 Edukinect (Exhibitor's Workshop)

Venue & Time	Paper title
TR714 1500 - 1630h	(EW011) Creating Authentic Assessments with Digital tools Read abstract

TRADESHOW HIGHLIGHTS

LIST OF EXHIBITORS

Venue:	Outside Lecture Theatre 1
Date:	19-21 Jun 2018
Opening Hours:	0900–1700 hrs

1	Carolina Biological Consultancy
2	Corwin
3	Edukinect
4	Expenovate Pte Ltd
5	Genetron Engineering Corporation Pte Ltd
6	Hodder Education
7	Labquip (S) Pte Ltd
8	Leave a Nest Singapore Pte. Ltd.
9	Marshall Cavendish Education
10	Mosaic Global
11	PerkinElmer
12	Spectra-Teknik (S) Pte Ltd
13	Springer
14	VedicLink

EXHIBITORS' PROFILES

CAROLINA BIOLOGICAL CONSULTANCY

Carolina Biological Consultancy institutes from Carolina Biological Supply Company (USA), the leading education resource supplier, providing world-class education support since 1927 with more than 500,000 educational resources.

Carolina Biological Consultancy is a key provider of STEM education in Singapore. As STEM education increasingly garners importance in Singapore, we work with teachers to develop innovative up-to-date teaching curriculum to equip students with the necessary knowledge and skills to give them an edge as they embark on career paths and step into the workforce.

CORWIN

Corwin, a SAGE company, is the premier provider of professional learning products and services that equip educators to improve teaching and learning. Corwin offers print books and ebooks, digital professional development products, institutes, and on-site consulting services for all types of educators at all stages of their careers. Corwin resources are authored by experts on the topics most relevant to you; formatted for hands-on, practical guidance; research-based and peer reviewed for quality; and suitable for professional learning settings and courses in education. Whether you are an administrator leading school reform or a teacher looking for solutions to daily challenges, we are committed to helping you reach your full potential so you can help children reach theirs.

EDUKINECT

Edukinect is a digital transformation partner for education institutions that want to optimize learning outcomes with technology enabled solutions. This digital transformation helps your organisation leverage the changes and opportunities in the industry. We work with institutions to help transform their classrooms using new age technology enabled learning, space management through focused consulting and implementation of technology to re-invent learning.

Edukinect empowers educators by providing technology enabled trainings to help educators integrate their learning plans using technology. As a Microsoft and a Google partner we work with educators and teachers on various courses that integrate the best of both technologies. Our courses range from Beginner, Intermediate and Advanced Office 365 trainings to Google in the Classroom and the G Suite Training. Please check out our full range of trainings at our website www.edukinect.com.

EXPENOVATE PTE LTD

Expenovate Pte Ltd is a one-stop supplier of educational supplies, manipulatives, science kits and hands-on-learning resources to schools. Established in 2005, we import from US, UK, Europe, Australia and much more to provide comprehensive catalogues to schools.

We also produced our own resources, most notably the Let's Explore Science Kits that we produced with Science Centre Singapore. To date, we have more than 80 products bearing our own brand "Learningstore".

Our web-portal www.learningstore.sg has more than 1000 products supporting hands-on learning. We are also present in Malaysia (www.learningstore.com.my) and Vietnam (www.learningstore.vn). Our other portal Scienz.net is the go-to site for science resources such as microscopes, data-loggers, anatomy models and many more.

GENETRON ENGINEERING CORPORATION PTE LTD

Genetron Engineering Corporation Pte Ltd was established in 1973 aiming to be one of the leading regional companies in Asia Pacific in providing quality services for our customers. Genetron has excelled in sales, marketing, training and consultancy in both educational and industrial sectors, involving electrical/electronic test & marketing instruments, telephone and acoustic test systems, microwave components, telecommunication and science products. Our customers include government agencies in Singapore, Ministry of Education, local polytechnics, local universities and private sector companies from Singapore and South East Asia as well as other projects cooperating partners including Malaysia, Brunei, Indonesia, Thailand, Philippines, Bangladesh, China, Canada and Australia. Our worldwide partners are United States of America, United Kingdom, Europe (including Germany, France, and Italy), India, Taiwan and China.

HODDER EDUCATION

Our company, Hodder Education Group, is one of the largest and most experienced publishers with over 100 years of publishing history.

Globally, we have published for almost every subject, and every learning level, providing resources to schools in over 140 countries worldwide.

Our expertise will allow us to provide the best support available to schools in Singapore, and help you deliver and develop the world-class practice that has made Singapore a global leader in education. As an official publisher of endorsed resources, we have worked with Cambridge International Examinations for over 25 years. Cambridge International Examinations work with the Singapore Ministry of Education to develop the O and A Level exams.

LABQUIP (S) PTE LTD

Labquip is a specialised laboratory equipment distributor. In the same business for over 30 years, we have grown to have offices and staff in 8 countries of Asia, and still growing.

The Labquip product range includes general laboratory equipment, instruments, and specialties in teaching sciences. We continue to add innovative products to work along with cutting edge technologies. Working with some of the best manufacturers in the business, we always provide excellent products and services.

Our clients are the Research Institutes, Hospitals, Schools, Regulatory Bodies, Industrial and Commercial Testing Labs.

We are not only a business but a growing family. The Labquip Family is present in all the countries from India to Taiwan. Together, we present an integrated sales, marketing and support force in the region, closely interlinked by daily and frequent communication, shared resources, unified marketing, technical support, stock and finance.

Labquip has a proven track record of partnerships with our suppliers and clients in every country in Asia. Your success is ours too.

LEAVE A NEST SINGAPORE PTE. LTD

Leave a Nest Singapore is a company comprised of researchers who wish to bring change to the world through "Advancing of Science and Technology for Global Happiness" We create opportunities to share knowledge, form new ideas through communication and bring new business to the world by working together with researchers and entrepreneurs.

MARSHALL CAVENDISH EDUCATION

As a leading provider of distinctive K-12 educational solutions in Singapore, Marshall Cavendish Education integrates research-driven educational approaches with innovative technology to facilitate students' learning and teachers' professional development.

For 60 years, we have crafted quality, comprehensive educational publications which have helped to contribute to the nation's outstanding performance, as showcased in international reports, such as TIMSS and PISA. Our educational solutions have been proven to be useful to different educational contexts worldwide. To date, our solutions have been adapted into multiple languages and used in over 60 countries.

Headquartered in Singapore, Marshall Cavendish Education has offices in Hong Kong, China, Thailand, Chile and the United States. Our brand is recognised worldwide for our work in ensuring excellent educational standards and we have proven to be a thought leader in Asian learning methods.

Our comprehensive print and digital solutions develop conceptual understanding and build 21st Century Competencies. They provide a blended learning experience that facilitates self-directed and collaborative learning. Through innovation, we continue to raise the quality of learning around the world, inspiring students and educators to learn and teach more effectively.

MOSAIC GLOBAL

Mosaic Global, leading Physics and Chemistry Olympiad organiser and educator, has an extensive expertise in education of gifted students. We aim to inculcate in students the habits of facing and overcoming challenging problems and to raise a genuine interest in science through novel approaches to higher learning and a continuous practice of solving complex questions as in Science Olympiads.

We have been organizing intensive Olympiad training courses in leading secondary schools in Singapore and overseas for more than a decade. All of our staff are MOE-endorsed educators and have extensive experience in all aspects of Science Olympiad education and organisation on international level.

Our brainchild projects, International Science Competitions, PhysiCo and ChemiCo, are unique competitive platforms to identify and reward gifted students. Mosaic Global has been organizing ChemiCo and PhysiCo for five consecutive years by now, and has established partnerships in several countries in Asia, Europe and Africa such as Australia, Indonesia, Japan and Nigeria. We are open to further collaborations with both governmental and private educational institutions around the globe to provide an accessible platform for Science education in Olympiad environment.

PERKINELMER

PerkinElmer is a global leader committed to innovating for a healthier world. Our dedicated team of about 11,000 employees worldwide are passionate about providing customers with an unmatched experience as they help solve critical issues especially impacting the diagnostics, discovery and analytical solutions markets. Our innovative detection, imaging, informatics and service capabilities, combined with deep market knowledge and expertise, help customers gain earlier and more accurate insights to improve lives and the world around us.

SPECTRA-TEKNIK (S) PTE LTD

Spectra-Teknik (S) Pte Ltd (STPL) was founded by Steven Tee on 24th May 1993. He has 40 years of experience in the scientific equipment distribution business. Prior to setting up STPL, he was employed by another company of a similar trade as General Manager responsible for business in Singapore, Malaysia and Indonesia. Due to his long time in this business, he has extensive connections with the customers in these 3 countries.

STPL's main businesses are in Singapore and Indonesia in the supply on various laboratory and field instrumentations to Government, Universities, Research and Educational Institutions/Schools as well as Industries in Semi-conductors, Petro-Chemicals, Pharmaceutical and Food.

Our main strategy is by mailing catalogs regularly. We have a mailing list of approximately 10,000 for Singapore and Indonesia. This mailing strategy enables the Company to grow very quickly. From a humble start with 3 staff, the Company now has 18 staff. STPL represents more than 20 scientific manufacturers, including Cole-Parmer (USA), Thermo Orion (USA), MMM (Germany), YSI (USA), Kern (Germany), VELP (Italy), and many other well known brands.

SPRINGER

Springer is a leading global scientific, technical and medical portfolio, providing researchers in academia, scientific institutions and corporate R&D departments with quality content through innovative information, products and services. Springer has one of the strongest STM and HSS eBook collections and archives, as well as a comprehensive range of hybrid and open access journals. Springer is part of Springer Nature, a global publisher that serves and supports the research community. Springer Nature aims to advance discovery by publishing robust and insightful science, supporting the development of new areas of research and making ideas and knowledge accessible around the world.

VEDICLINK

VedicLink is a local academic-focused instructional design studio that has introduced whiteboard animation and various animated blended learning courseware in NUS, NIE and MOE across various modules, as well as for MOOC platform such as Zuni in different languages. Our current work is a nationwide project, in association with JCs, which will be featured on MOE's LMS 'Student Learning Space'.

Want to create a whole new blended learning experience for your courses or training? Immersive Virtual Reality? Animated Videography? Engaging courseware both digital and print? Come talk to us!

SYNOPSIS OF EXHIBITORS' WORKSHOPS (EW001 – EW011)

CAROLINA BIOLOGICAL CONSULTANCY

(EW001) STEM Applied Learning Programmes

STEM ALP help students appreciate the relevance and value of what they are learning in the academic curriculum to the real world, and develop stronger motivation and purpose to acquire knowledge and skills. This workshop will inform participants on how STEM ALP can enable the application of thinking skills and the integration of knowledge across subject disciplines.

EDUKINECT

(EW007) Creating 3D Content for Science

Using Microsoft tools the workshop will feature the following highlights:

1. Using 3D application to create you own 3D models for your science classes
2. Increasing sustainability in your classroom through the Power of OneNote
3. Collaboration and Communication in your classroom through the power of TEAMS.
4. Hands On Labs for each of the above listed applications.

Teachers and School leaders walk away from this workshop with tools that they can put into action immediately within their classroom.

(EW011) Creating Authentic Assessments with Digital tools
Using digital tools such as Microsoft Forms, Sway learn how to create authentic assessments.

The workshop will feature 2 key tools - Forms and Sway and showcase both they can be intertwined together to create authentic assessments that can be accessible by your students on any device.

EXPENOVATE PTE LTD

(EW010) STEM does not mean scary coding!! - Introducing fun and non-intimidating STEM for lower primary students, without the nightmare for the teachers.

STEM is inevitably an important part of modern day science curriculum. While Science is not taught in lower primary, many schools and kindergartens have pushed for STEM-based lessons to be introduced to their young learners.

Unfortunately, STEM is often linked to robotics and coding. This is not just over-whelming for the pupils but also intimidating and challenging for the teachers.

The workshop is about the various STEM initiatives, products, and lesson plans that teachers can adopt to introduce STEM-based activities to their young learners. There are many things that they can do to make it engaging, fun and relevant.

GENETRON ENGINEERING CORPORATION PTE LTD

(EW008) Think Technology, Think Science

Objective:
Integrating the powerful and yet easy-to-use wireless sensors for data collection with mobile devices in a fun filled demo / hands-on session

STEM:
It's so Hot! It's Melting! Challenge

Learn how to integrate technology into STEM programs that can build scientific literacy, deepen understanding and increase student engagement in science, technology, engineering and math.

Environmental Science:
A short walk-about session in the vicinity to monitor environmental conditions with GPS.

Biology / Chemistry:
Investigating various parameters using common beverages taken from stores.

Physics:
Studying the relationship between position, velocity, acceleration and force using a Smart Cart.

LABQUIP (S) PTE LTD

(EW002) Wireless probeware technology in Science - with hands-on

This workshop will provide an introduction on how to empower your students and unleash their curiosity for science and discovery. Wireless or USB—the versatility is built into the sensors so you have the flexibility to choose. Go Direct sensors connect directly to student computers, chromebooks, or mobile devices so there's no interface needed. That's freedom, versatility, and boundless opportunity. The Go Direct sensors are perfect for educators who are using computers, chromebooks, and mobile devices for data collection, need an affordable solution that includes free software and all-in-one sensors, plan to equip a new science laboratory and who are new to probeware

LEAVE A NEST SINGAPORE PTE. LTD

(EW003) Be an engineer to design future

Leave a Nest Robotics Lab nurture basic engineer skills which is needed not only for engineers but for all future leaders. Participants will gain knowledge about importance of understanding materials and process to design a robot or a machinery which can provide solution for a problem faced. We do not want to teach how to build a robot but we teach our students to become an engineer who can design solution through use of engineering skills.

MARSHALL CAVENDISH EDUCATION

(EW004) Designing for Applied Learning in STEM

Applied Learning emphasises authentic and practice-oriented learning experiences that gives students opportunities to acquire skills and qualities based on the practical application of knowledge in real-world contexts. This supports the development of 21st century competencies and values in our students. In this session, we will explore some design principles with examples in STEM and how teachers can assess Applied Learning in our students.

MOSAIC GLOBAL

(EW005) Gifted and Science Olympiad education

About PhysiCo & ChemiCo

Our International Science Competitions, PhysiCo and ChemiCo, aims to provide a unique competitive platform to identify and reward young geniuses and create a talent pool for the future academic advancements. These Olympiads are designed not only to test the basic knowledge learnt in school but also to stimulate analytical and critical thinking ability and increase problem solving skills of a student. Hence, PhysiCo and ChemiCo are not just another Olympiad examination but they motivate students to strive for academic excellence and help bring out the best in a student. All the participants who take ChemiCo and PhysiCo are provided with Individualised and detailed assessment reports to support their targeted learning. It helps teacher monitor student's understanding of the science topics, level of knowledge and power of reasoning.

Benefits of Olympiad spirit

Scoring high in PhysiCo and ChemiCo requires more than just knowledge of the concepts. Students are tested on their ability to use time efficiently and strategize on tackling the questions in the right order, from the easiest to the most difficult. This cultivates strategic and analytical thinking in a student which is useful in any competitive examinations. Most of the Olympiad questions are non-routine and demands higher order thinking skills. Only the students with the qualities of a curious mind and independent learning can achieve best results. ChemiCo and PhysiCo promotes to create this kind of an Olympiad environment in which the spirit of exploring prevails.

Objectives of ChemiCo & PhysiCo

A good rank in the Olympiads develop a sense of confidence in the students and help parents identify the talent of a student and thus contributes to the overall development. ChemiCo and PhysiCo aims to recognise and reward high-achieving students and provide support towards academic excellence. For the students who aspire to be scientists, there is a higher prospect of success in university with strong science background. Therefore, through these Olympiads we aim to establish the ground for future scientists by inculcating the habit of facing and overcoming challenging problems and raising interest in Science.

SPECTRA-TEKNIK (S) PTE LTD

(EW006) Science of Water

"Water is the driving force of all nature" - Leonardo da Vinci

Water is essential for the survival of living things. Although about 70% of Earth's surface is covered by water, but how much do we know about the quality of the water around us?

In this workshop, we will explore the science behind water quality and the various instruments for efficient and effective measurement for various experimental needs.

The topics we will cover in this workshop are as follows:

1) pH – Acidic vs Alkaline. What does this really mean?
2) Conductivity – Saltiness. How to measure that?
3) Dissolved Oxygen – An indicator of water pollution
4) Ion selective electrodes – Quick and efficient technique for specific ion concentration measurement
5) Turbidity – Its role in water quality measurement
6) Introduction of the relevant instruments for measurement
7) New Product Launch: Thermo Orion STAR T900 series Titrator

VEDICLINK

(EW009) Reimagined Blended Learning

Putting online content up but have difficulty sustaining learner interest? Fear no more! In this workshop, we will work through techniques that YouTube creators use to capture audience's attention. Come join us and find out how to create digital learning that captivates student attention!

ABSTRACTS OF PRESENTATIONS

(A173) FACILITATING THE USE EDUCATIONAL RESEARCH BY TEACHERS TO ADDRESS CONCERNS IN PRACTICE

Kim Chwee Daniel TAN, *National Institute of Education, Nanyang Technological University, Singapore*

Abstract

Research is a systematic inquiry into phenomena giving rise to primary data which are based on observations or experiments, or secondary data which are derived from an inquiry into primary studies. Though not always correct and subjected to revision, research knowledge can provide different perspectives of practices in school and can balance the sole use of personal experience or practitioner knowledge in classroom teaching, which is also not always correct. Studies have found that teachers may not be able to find research that is relevant and practical for their immediate needs or areas of concern, and even if the relevant research can be found, teachers may have difficulty in reading, understanding and acting on the research reports. These studies have suggested that intermediaries, organisations or individuals who are known to, and trusted by, teachers, can help teachers to select and interpret relevant studies, explain how these studies can help improve teaching and learning, discuss with the teachers if the findings and suggestions from the studies are feasible in their context, and work with teachers to facilitate the use of research in their classroom practices. Thus, a study was conducted to determine how an intermediary (the author) could facilitate the use of educational research by three chemistry teachers to address their common concerns in the classroom. Case study was used by the author who conducted semi-structured interviews with, and surveys of, teachers and students, and held formal and informal conversations with the teachers face-to-face and through emails. The teachers preferred not to have their lessons observed, so relevant lessons were audio-recorded. These audio-recordings of lessons, as well as, student and teacher artifacts provided additional data for the study. Firstly, this paper describes the interactions between the intermediary and the teachers at the initial stage of the project to decide on the area of concern to focus on. This is important to motivate teachers to agree to participate in the project and continue their participation in the project as it will be useful to them. The teachers decided that they would like to address student difficulties in planning experiments because their students were not able to answer examination questions related to the planning of experiments well and they had difficulties teaching the topic. The paper next details the decisions made by the intermediary in the selection of possible educational research to propose to the teachers, how the presentation of the possible studies was developed and carried out to make the studies easier for the teachers to understand, and how research on productive failure and cognitive apprenticeship was selected by the teachers to guide the development of instructional material and strategies to address their students' difficulties in planning experiments. The details of the study may guide other intermediaries or researchers wishing to carry out a similar intervention in collaborating with teachers to facilitate the use of educational research to impact classroom practices.

Back to programme

(A174) HOW PRESENTERS' LIKEABILITY AFFECTS PEER ASSESSMENTS OF THEIR PRESENTATION SKILLS: A STUDY OF SINGAPOREAN SCIENCE STUDENTS

Vahid ARYADOUST, *National Institute of Education, Nanyang Technological University, Singapore*

Abstract

Studies have proven that likeability is deeply associated with certain socio-psychological constructs such as social status, personality, and peer judgements. Likeability can also play a significant role in audiences' and raters' evaluation of oral presentations. Oral presentations are particularly important in science education where educators attempt to prepare their students for public and scientific events as well as localized university or school presentations. In classroom settings where peers may partly grade the students' oral presentation skills (as a type of formative assessment), the likeability factor can influence rating decisions, and depending on the stakes of the assessment, likeability may also affect the validity of the scores. For instance, Ciarrochi and Heaven (2009) showed that likeability causes overestimation of peer assessment in opposite-sex ratings but underestimation in same-sex evaluations. That is, likeable students (of opposite sexes) are more likely to be awarded higher ratings and be regarded to have higher status by their peers. Likeability also leads to cognitive biases affecting individuals' impressions and judgements towards objects or other people. As a case in point, in 1996, Engelhard found that even trained raters who rate student performance are also influenced by these cognitive biases. Although in this research Engelhard did not elaborate on why such biases occur in rater performance, existing research suggests that physical attractiveness and amiability (two important likeability components) may contribute to such observed biases. To further understand how likeability influences peer assessments of science students' presentation skills, the author conducted the present study on Singaporean science students. There were two main aims for this research: (1) to examine the relationship between peer-rated likability and peer-rated oral presentation skills of 96 student presenters enrolled in a university science communication course, and (2) to investigate the relationship between student raters' severity in rating presenters' likeability and their severity in evaluating presenters' skills. Students gave an academic presentation and then changed roles to give rating to their peers' performance and likeability, using an 18-component oral presentation scale and a 10-component likeability questionnaire. The data collected, then, were validated using many-facet Rasch measurement, and structural equation modelling was adopted to examine the effect of likeability on peer assessments. At an aggregate level, likeability explained 20% of the variance of the oral presentation ratings and 8% of student raters' severity. At a component-level, multiple cause effect relationships were found, with the likeability components explaining 6% to 30% of the variance in the oral presentation components. Therefore, it is suggested that peer ratings method can be employed in low- and medium-stakes assessments, provided that the students are well-trained, and that the sources of construct-irrelevant variance are identified and possibly nullified.

Back to programme

(A176) EFFECTIVENESS OF DIFFERENTIATED INSTRUCTION ON STUDENTS' LEARNING OF CHEMISTRY CONCEPTS

Shyh Yuan Don YEO, *NUS High School of Math and Science*
Chong Lee Jason TAN, *Raffles Institution*
Tuck Chuen Stephen LOW, *Punggol Secondary School*
Kheam Soon Alex LIM, *CHIJ Katong Convent*
Pui San TAN, *Swiss Cottage Secondary School*

Abstract

Differentiated Instruction (DI) can be described as a classroom practice through which teachers proactively modify content, teaching methods, resources, learning activities and student products to address the diverse needs of students (Tomlinson et al., 2003). Research on DI and its impact on students' learning in Singapore classrooms is limited. A few discuss addressing students' learning needs at a systemic level against what teachers could do in the classroom. Banding according to results achieved at a preceding stage is often the initial approach to sort students for teaching. However, questions related to DI in the classroom and specifically student learning have yet to be addressed. The concepts of zone of proximal development (ZPD) and more knowledgeable others (MKO) inform the features of differentiation. Teachers would plan instruction to extend the student to just above the current level of development, building on that which the student already knows and nudging the student to move ahead to greater challenge. Working in a group setting together with the teacher affords social interactions with "more knowledgeable others". Bransford, Brown, & Cocking, (2000) assert that in such a setting, "students might help one another solve problems by building on each other's knowledge, asking questions to clarify explanations, and suggesting avenues that would move the group toward its goal" (p. 25). This study is conducted in five different secondary schools in Singapore. Lessons for a topic were crafted and implemented specifically to include the two features of DI. The instructional objectives were identical for both experimental and comparison groups. An independent t-test, assuming equal variance was used to analyse for statistical significance to the difference in the post-test mean scores between the groups. Paired t-tests were used to analyse the difference between the means of the post-test and pre-test scores for the experimental group, and also the comparison group. Qualitative feedback from surveys were administered after completing the intervention to supplement the results. The aim was to gather insight to students' perception and experiences of the intervention that may not be revealed via test scores. Increment in the mean scores for the post-test relative to the pre-test for the experimental group for most schools were statistically significant. Acknowledging the variable of different content assessed for the respective schools' pre-tests and post-tests, the data suggests DI may have resulted in a positive effect on students' understanding of chemistry concepts in some topics. Feedback from survey shows positive learners' experience as there is greater opportunity for students to discuss and learn from each other, and felt less pressurized as they solve questions together. In addition, the more able students get to move ahead by solving more challenging questions. The results of the study seem to suggest that DI which focused on ZPD and MKO brings about positive learners' experience in the learning of Chemistry in the classroom. More time may be necessary for students to get accustomed to the "new" learning method for greater impact on test scores.

Back to programme

(A179) PAYING ATTENTION IN CLASS: WHAT DO SCIENCE TEACHERS TAKE NOTE OF IN THE CLASSROOM?

Melvin CHEW, *National Institute of Education, Nanyang Technological University, Singapore*
Aik Ling TAN, *National Institute of Education, Nanyang Technological University, Singapore*
Seng Chee TAN, *National Institute of Education, Nanyang Technological University, Singapore*

Abstract

This study examines the areas that secondary science teachers pay attention to while they are teaching. Understanding and reflecting on what teachers give their attention to as lessons unfold moment-to-moment helps teachers and researchers to better anticipate pedagogical moves in classrooms. Using wearable eye-tracking glasses and interviews, the noticing patterns of three secondary school science teachers were examined. One of the teacher taught a theory lesson on respiration while the other two teachers conducted a laboratory practical lesson on circuits. Each of the lesson lasted one hour. Analysis of the gaze patterns of these teachers revealed that in the complexities of the science classrooms, teachers are capable of noticing different and diverse things in a short span of time. They are able to shift their attention rapidly to areas that require their action. The different things that teachers have to pay attention to include the computer screen, the projector screen, individual students, groups of students, the textbook, teachers' notes, events taking place outside the classroom as well as laboratory equipment. Contrary to what we initially believe, teachers do not spend large amounts of time focusing on students as a class. The students in the classroom are merely one of the many things that fight for the attention of the teacher. Rather, in a didactic whole class instruction setting, teachers' pay attention to specific students, the computer screen, the projector screen, and also movements outside of the classroom.
In a laboratory setting, while teachers generally pay most attention to the laboratory equipment that students work with, the amount of time spend on the laboratory equipment varies in relation to noticing other things. For example, teacher A spent a proportionally higher amount of time noticing the laboratory workbooks on top of the equipment while teacher B spends relatively less time noticing the workbooks as compared to the equipment. Together with perspective shared by the teachers during the interview, it suggests that teacher A was concerned about how students will translate their observations into written text format in their workbooks while teacher B tends to emphasise on the practical aspects of the experiment like checking on the setup. Post observation interviews revealed that while the teachers were generally aware of what they look at in the classroom, they had little idea how frequent or how much time they actually gave attention to the different aspects while they were teaching. They also do not think about why they notice certain things more than others. Pedagogical decisions are made in the classroom tacitly most of the time as there are many decisions that the teacher needs to make since the situation in the classroom changes rapidly as well. Understanding the patterns of teacher noticing and using it as a reflective tool allows for a more nuanced and predictive way to understanding teachers' in-the-moment decisions and actions. In practice, studying teacher noticing enables us to provide more targeted and meaningful feedback to teachers for improving their practices.

Further, patterns of noticing provide evidence for underlying teacher cognition.

Back to programme

(A180) LEARNING TRAJECTORY OF SCIENCE UNDERGRADUATES WORKING AS INTERNS IN RESEARCH LABORATORIES

Cassander TAN, *National Institute of Education, Nanyang Technological University, Singapore*
Aik Ling TAN, *National Institute of Education, Nanyang Technological University, Singapore*

Abstract
There has been a greater emphasis on engaging science undergraduate students in authentic scientific research. The term "authentic research" refers to the opportunities provided for learners to work under the supervision of a practicing scientist, usually in a research laboratory. Students who take part in authentic scientific research work with faculty and research staff work over an extended period of time. This authentic experience exposes students to the field of science practice and to gain insights about the communal nature of science. Many science undergraduate programs have incorporated the component of laboratory internship. However, these internships programs are both labour and resource intensive. As such, it is important to ascertain that the learning that takes place during such internship is meaningful. The purpose of this paper aims to illumine the types of learning experiences that science undergraduate gain from the laboratory internship attachment and then map the knowledge and skills learnt to the experiences of the intern. This paper analyses the emotional state of the undergraduate during the different phases of the attachment to determine the learning trajectory of science undergraduates while participating in laboratory internship program. An in-depth case study approach was used in this study. A pre-interview was conducted with the participant at the beginning of his science research project. Following that, detailed field notes were collected while observing the participant working in the laboratory over a period of four months. Each time, the participant was being observed for two to four hours. After the participant has completed his science research project, a post-interview will be conducted. The grounded theory was adapted to code and categorize the qualitative data obtained to identify the key activities that occur in the laboratory. The participant (pseudonym assigned - Tom) in this study is a year three life sciences major at the National University of Singapore (NUS). He was working with a laboratory executive, under the supervision of a professor, on a project that aims to explore the effect of the anti-fungal drugs (which can treat Candida albicans) on the formation of biofilm by Candida glabrata. This project fell under the Undergraduate Research Opportunities Programme in Science (UROPS), a two-semester long program that has allowed him to actively engage in the process of scientific research and inquiry. The learning trajectory of Tom started off with scaffolding and modelling by the research mentor which allowed Tom to work independently. While working independently, he gradually created a sense of familiarity with the laboratory protocols to the extent that he could conduct the experiments fluently. During this process, he began to understand the rationale and purpose of the protocols as he attempted to refine and discuss them in relation to the results he obtained with his supervising professor and research mentor. While going through this learning trajectory as an intern, Tom came to better appreciate the practices of science, particularly, the repetitive and unpredictable nature of authentic science experiments, which are currently still absent in mainstream school science and other undergraduate science modules.

Back to programme

(A182) SUBCULTURES OF LOWER TRACK SCIENCE CLASSROOMS: AN ANALYSIS OF POWER RELATIONSHIPS

Tang Wee TEO, *National Institute of Education, Nanyang Technological University, Singapore*

Abstract

Subculture is defined as: "A relatively diffuse social network having a shared identity, distinctive meanings around certain ideas, practices, and objects, and a sense of marginalization from or resistance to a perceived "conventional" society" (Haenfler, 2014, p. 16). As compared to dominant and mainstream classroom cultures imposed and reinforced by teachers, subcultures may sometimes seem weird, childish, untamed or silly. I argue that rather to deny or dismiss the existence of subcultures or contest them in power struggles with students, it is worthwhile for teachers to understand how it plays out in the science classroom to shape the outcomes of teaching and learning. Rather than causing problems, subcultures often provide solutions to troubled children in the form of a meaningful community. The theoretical framework used to examine subculture is symbolism interactionism (Blumer, 1969) and I use it to unpack the teacher-student interactions. In this paper, I focus on the behaviours of the social actors. In particular, I examine the power relationships between the teacher and students during the science lessons as power play become an evident phenomenon during the lesson. This study involved the study of subculture in a Secondary 2 (equivalent to Grade 8, aged 14) lower track science classroom in a mainstream, public, and co-educational secondary school located in the eastern part of Singapore. All the science lessons, each lasting between 35-70 minutes, in the academic year was videoed. The analysis was done using the emergent coding method and constant comparative approach. From the in-depth analysis of one lesson video, evidences of teacher-dominance, student-dominance, and balanced power relationships were identified and mapped against the school culture of care and academic achievements against type of power relationships in a two-dimensional matrix. Specifically, in the cell of "teacher dominance" versus "academic excellence", the following evidences were found: (1) expectations on student accountability, (2) maintaining class order, (3) instructing on decorum, (4) providing information, and (5) disapproves students making unnecessary distracting noise. In the cell of "teacher dominance" versus "care", the following evidences were found: (1) making sure students have materials to study, and (2) making sure students have access to writing materials. In the cell of "student dominance" versus "academic excellence", the following evidences were found: (1) student trying to "own" teacher, and (2) teacher is unable to answer the students' questions. In the cell of "Balanced power relationships" versus "academic excellence", the following evidences were found: (1) getting students to recall what they needed to do for homework, (2) teacher prompted student turn-taking through student nomination, (3) teacher encouraging students' inputs, (3) answering students' question, (4) student jokes, and (5) teacher disattend. The findings show that power relationships are embedded in the subculture of lower track classrooms. I will use this to theorise about subcultures of lower track classrooms and inform science classroom practice.

Back to programme

(A186) FACTORS AFFECTING CHEMISTRY ACHIEVEMENT AND ACADEMIC PERFORMANCE AMONG FRESHMAN NURSING STUDENTS

Rizalina ANDAMO, *Philippine Normal University*

Abstract

Identifying the factors affecting academic performance which enhance retention rates and contribute to academic success demands timely and effective intervention in the classroom. It also ensures that students are better prepared in facing challenges in a dynamic and ever-expanding workplace. This study identified factors and investigated their effects on Chemistry achievement and academic performance among freshman nursing students of Our Lady of Fatima University. One hundred and five (105) students, grouped according to their grade-point average (GPA) as high ability (HA), middle ability (MA) and low ability (LA), were randomly selected to accomplish a questionnaire consisting of five (5) sets of questions for the variables academic competence (AC), test competence (TC), time management (TM), studying techniques (ST), and test anxiety (TA). Scores were tallied with one (1) as the highest and five (5) the lowest. Descriptive normative survey type with predictive analyses was employed in this study. Frequency, percentage, mean, standard deviation, Pearson Product-Moment Coefficient of Correlation, F-test using the ANOVA I procedure, and non-stepwise multiple line ar regression ware utilised in the analysis of data. Results revealed that the students had the same level of Chemistry achievement and GPA. In terms of academic performance, MA group was most homogeneous (M = 2.37; SD = 0.13) and LA group was most heterogeneous (M = 3.37; SD = 0.35). In terms of Chemistry achievement, the HA group was most intact (M = 1.78, SD = 0.32) and LA group was least intact (M = 4.67; SD = 0.76). The HA students got better remarks in most of the performance variables than the MA and LA students. The three ability groups had moderately positive overall performance score (OPS) or weighted mean of the five performance variables, but HA group had higher OPS than the lower groups. The correlations among the variables ranged from low to marked substantial, except between ST and CHEM and TA and ST with negligible correlation. The five selected performance variables AC, TC, TM, ST, and TA, taken individually and as a group appeared to be potential factors that affect Chemistry achievement and academic performance, but AC, TM and OPS were found to be the best or strongest predictors of Chemistry achievement and academic performance. Results of the study suggest that incoming freshman students be admitted and grouped on the basis of their high school GPA to maximize learning and make it more effective. Similar and follow-up studies can help monitor students' performance so that necessary assistance and guidance will be properly given to them. Furthermore, programs and seminars on academic competence and time management will enable students to assess themselves and help them perform better. These could lead them to the fulfilment of their common goal, to achieve academic success.

Back to programme

(A187) TEST ANXIETY, SCIENCE AND ACADEMIC PERFORMANCES IN SENIOR HIGH SCHOOL STUDENTS

Rizalina ANDAMO, *Malinta National High School*

Abstract

Test anxiety is a frequently studied multidimensional construct in many educational systems. It has been regarded as an important factor in all fields of studies and is well researched in many countries. Empirical literature associates test anxiety with student performance. Science, as part of school curriculum and which contributes greatly to overall performance of students, has always been a difficult subject for many students. In the Philippines, few studies explore the relationship between test anxiety and science performance. Hence, the study investigated the relationship between test anxiety and science performance to become basis for structuring programs that will address students' test anxiety and its influence on their academic performance. A population of 105 senior high school students, from first batch of K+12 Curriculum graduating in year 2018, were surveyed using the Test Anxiety Inventory (TAI), a widely used self- report instrument for measuring test anxiety in high school and college students consisting of 20 statements in which students are asked to report how often they experience anxiety symptoms before, during or after taking tests. A 4-pt Likert–scale yielded a total test anxiety score and subscale scores to measure worry and emotionality, the two major components of test anxiety. Using sample-specific means and standard deviations, low, moderate and high test anxiety groups were formed. To determine the students' test anxiety level and its relation to their age, gender, Science performance and general weighted average (GWA), statistical tools mean, frequency, standard deviation, t-test for independent means, and one-way analysis of variance (ANOVA) were utilised. Results revealed that senior high school students have moderate level of total test anxiety (M=56.21, SD=11.04), emotionality (M=20.90, SD=5.11), and worry (M=23.45, SD=4.90). Furthermore, results also showed that there are significant negative relationships between TAI scores and Science performance; significant negative relationships between TAI scores and GWA; significant positive high correlation between Science performance and GWA; no significant difference in test anxiety scores between males and females (t=-0.61, p=0.54); no significant difference in Science performance among high- (M=71.75, SD=4.73), moderate- (M=55.77, SD=5.62), and high- (M=40.32, SD=5.04) test anxious students, [F (2,138)=2.74, p=0.068]; and significant difference in GWA among the three anxiety groups [F (2,138)=3.16, p=0.046]. Results of the study suggest that test anxiety is just one factor that can affect students' performance. Hence, it is recommended that students, for accommodation purposes, be subject to eligibility test based on predetermined clinical criteria to ensure that they are accommodated accordingly and that learning is maximized; seminars and programs be given to involve not only teachers and students but also parents, guidance counselors and school administrators; and conduct of follow up and further studies that will look into other factors that can predict Science and overall performances of students across levels.

Back to programme

(A192) DEVELOPMENT OF METACOGNITIVE-ENHANCED LEARNING RESOURCE MATERIALS IN MOLECULAR GENETICS: EFFECTS ON STUDENTS' METACOGNITION AND CLASSROOM ENVIRONMENT

Richard Deanne SAGUN, *Ateneo de Manila Junior High School*
Maricar S. PRUDENTE, De La Salle University

Abstract
Most science classes are often set towards understanding of complex scientific concepts. At some point, students are bombarded with so much information that they find them hard to comprehend. This leads to a greater need to guide and reinforce the students on how they can understand complex concepts in science through introspection and self-regulated study techniques. Metacognition relates to thinking about one's thinking. It refers to how an individual, especially learners, plan, monitor, and assess their understanding and performance. Metacognition promotes critical awareness of one's thinking and learning. The study highlights the conceptualization, implementation, and evaluation of the Metacognitive-Enhanced Learning Resource Materials in Molecular Genetics (MELRMMG). The MELRMMG consists of four (4) learning modules that are carefully designed and planned corresponding to specific topics in molecular genetics. All modules were structured in such a way that the students will become aware of their thinking in line with the concepts in molecular genetics This is also in response to the research gaps identified by Zohar & Barzilai (2013) in their review of research on metacognition in science education: a) attention to the development of learners' metacognitive knowledge and b) controlled research designs providing causal evidence regarding the effectiveness of metacognitive instruction in science learning. The Plan-Do-Study-Act (PDSA) cycle approach was employed in the study. Both quantitative and qualitative research techniques were explored to answer the problems of the study. A total of ninety-five (95) Grade 10 students studying in an all-boys, Catholic private junior high school in the Philippines participated in the study. The students were exposed to different metacognitive activities as they learn and understand topics in molecular genetics: nature and characteristics of DNA, DNA replication, protein synthesis, and genetic mutations. Metacognitive prompts, journal reflection, concept mapping, and inquiry-based activities were some of the learning activities done by the students. Quantitative data were gathered using the Metacognitive Assessment Inventory (MAI) by Schraw and Dennison (1994) and the Metacognitive Orientation Learning Environment Scale-Science (MOLES-S) by Thomas (2003). Both instruments were given as pre- and post-assessments. Qualitative data were gathered using the students' responses in metacognitive prompts, reflections, and semi-structured interviews. Results showed a significant effect on the enhancement on the students' metacognitive skills and improvement on the metacognitive orientation of the classroom. The students, after being exposed to a metacognitive learning environment, became more aware on their thinking processes especially how they identify their learning challenges in molecular genetics. They were also equipped with the skills in self-regulated study techniques to address their learning challenges. Furthermore, this study reinforces the critical links between science education, metacognition, and learning environments. There is a great need to develop and structure science classroom environments that are favourable to the development and enhancement of students'

metacognition. In turn, this will result in a thorough conceptual understanding of science topics, specifically those involving molecular level processes.

Back to programme

(A193) EXPLORING PRE-SERVICE SCIENCE TEACHERS' REFLECTIVE QUALITY ON INQUIRY-BASED LEARNING WITHIN A PROFESSIONAL LEARNING COMMUNITY

Jeerawan KETSING, *Kasetsart University*
Noriyuki INOUE, *Waseda University*
Sandy BUCZYNSKI, *University of San Diego*

Abstract
Promoting pre-service teachers to teach science through inquiry has long been a central goal for teacher preparation programs. However, literature documents pre-service teachers having difficulties to create an inquiry-based learning, particularly in real classroom settings. With this regard, literature recommends teacher preparation institutes to help future teachers to cope with this challenge by providing them opportunities to learn from experienced teachers, with whom the newcomers plan, implement, and reflect upon their teaching practices within a supportive professional learning community (PLC).

Additionally, previous literature also notes that the teacher's professional growth is not guaranteed by uncritically following series of activities. What truly matters underneath the PLC is the quality of reflection the newcomers have on their teaching actions. Unfortunately, little evidence is available on what reflection beginners have during their initial stage of learning prior to their teaching profession? and how beginners see themselves from being failure to become successful in inquiry-based learning, especially in the PLC context. Therefore, this qualitative case study aims to explore two pre-service teachers' reflective quality on inquiry as they had gone through the PLC with cooperating teachers and a university mentor during field experience.

By tracking the teachers' reflective quality, data were drawn from classroom observations, individual interviews with the pre-service teachers, and their reflective journals. Data analysis guided by two theoretical lenses, one proposed by Zeichner and Liston (1990) and another described by Goodman (1991) and LaBoskey (1994). According to Zeichner and Liston (1990), reflective teaching practice can be distinguished into four versions: academic, social efficiency, developmentalist, and social reconstructionist. Given this distinction, Zeichner and Liston (1990) believe reflective teachers should involve every version of reflection when thinking about their teaching. Another analysis framework used for guiding this study is from Goodman (1991) and LaBoskey (1994) who viewed reflection in three domains: content, process, and attitude.

Findings from the individual cases revealed that after working through the four-month PLC, one pre-service teacher developed a high quality of reflection on her teaching practice. The teacher's reflective thinking evidenced four versions of reflection described by Zeichner and Liston (1990). On the other hand, another teacher faced difficulty to see her teaching action in the light of social efficiency and social reconstructionist. In other words, this novice teacher struggled to view her classroom and school as a place for applying teaching strategies suggested by literature. She did not envision her class as a small society where students and teacher learned about equity and social justice. However, after learning through the PLC, both pre-service teachers had

a positive mindset on learning how to teach. The teachers were willing to learn from mistake and change their practices in ways that benefit children's learning. Findings from the current study suggest that the PLC seems to provide a preferable outcome regarding pre-service teachers' professional development. Even if the improvement of individual teachers were at a different pace, the PLC orchestrated open-mindedness and responsibility of the pre-service teachers on closing the gaps between their goals and their practices in classrooms.

Back to programme

(A198) SCIENCE CLASSROOM TEACHING IN SINGAPORE: INITIAL FINDINGS FROM THE CORE 3 RESEARCH PROGRAM

Dennis KWEK, *National Institute of Education, Nanyang Technological University, Singapore*
Yew-Jin LEE, *National Institute of Education, Nanyang Technological University, Singapore*
Hwei-Ming WONG, *National Institute of Education, Nanyang Technological University, Singapore*

Abstract
How do teachers teach science in Singapore? This important question has little empirical basis or research findings although this situation is now beginning to change with the recent CORE 3 research program conducted by the authors from the National Institute of Education, Singapore. The methodological focus and design of Core 3 is on "everyday classroom pedagogy, on the intellectual and discourse work of teachers and students in the classrooms" (Luke et al, 2005, p.9). We sampled 10 mainstream schools and teachers in average classrooms (total 90 lessons in Primary 5 and Secondary 3 (Physics)). We segmented all video recorded lessons into 5 minute phases and coded these for key pedagogical practices that we believe should be happening in classrooms, drawing from both the local curriculum intentions and international understandings of what science teaching and learning should be about. We also conducted interviews with teachers and students. What we found was that In terms of Knowledge Focus, there was an emphasis on Factual Knowledge in 59% of phases per lesson for P5 (46% in S3). Procedural Knowledge was less in P5 (39%) compared to S3 (61%) and Conceptual Knowledge was present in P5 (49%) and S3 (43%). We did not see a lot of Epistemic Knowledge (4% in both P5 and S3) where teachers and students debate, justify, deliberate on knowledge claims, nor did we see a lot of Metacognitive Knowledge (4% in both P5 and S3). The results are broadly comparable to the Singapore PISA 2015 findings, where Singapore Science shows a stronger emphasis on procedural and epistemic knowledge than content knowledge. In terms of Epistemic Talk, we found respectable proportions of Explanatory Talk (42% in P5, 40% in S3). Procedural Talk was stronger in S3 (61%) than in P5 (38%), but there was room for Epistemic Virtues Talk (5% in P5, 1% in S3) where talk focuses on the nature of science, justifying and arguing for scientific claims. Likewise, an average of 86% of all phases in P5 and S3 had teacher closed questions with students requiring to respond with the correct answers, and 25% in P5/S3 with teacher open questions where there are multiple answers. In terms of the Scientific Skills that are exemplified in the Science Syllabus, we find that observation, communicating in scientific terms, analysing patterns, compare and contrast, and inference to be respectable in P5 and S3 classrooms.
We also note that P5 and S3 students tend to engage in investigation far more than other scientific processes such as decision-making or creative problem solving. In terms of Scientific Inquiry, using the 5E model of inquiry, we observe largely teacher-directed inquiry rather than student-directed inquiry. Teachers tend to pose questions, provide materials, direct students to collect data, guide students in formulating explanations, provide possible knowledge connections, and give students steps and procedures for communication. Some initial findings from video studies of these 90 lessons will be shared and recommendations for what constitutes a Singapore pedagogy of science will be put forth.

Back to programme

(A203) EXAMINING THE PEDAGOGY OF PROBLEM SOLVING AND CRITICAL THINKING USING A NEW LENS - GEOGRAPHIC INFORMATION SYSTEMS

Josephine DESOUZA, *Ball State University*

Abstract

A spatial phenomenon that is happening within the location of a framework or context is part of students' lives. It is important for them to become cognizant of the ambient geography that allows them to make sense of their environments. The pedagogy of geographic inquiry is very similar to the STEM pedagogy of scientific inquiry except for one big difference: space. This presentation advances the theme of the ISEC conference in that it discusses how we can examine societal issues through the lens of geospatial technologies, specifically GIS and ArcGIS online to educate preservice teachers about problem solving using innovative technologies. It is critical that this generation of students becomes facile with geospatial techniques and methods; properly trained educators promote student engagement as those students find out for themselves the many ways technology enables scientific discovery. The positive exposure to any science or technology can establish a curiosity that could potentially lead to more students ultimately pursuing STEM fields as careers. Additionally, projects can provide benefits to society when students, in conjunction with their teachers, learn how to gather and interpret environmental data. They become aware of just what their data mean and determine whether there are negative consequences, they become citizen scientists. The foundation of geographic thinking is based on the knowledge of where things are located and how its location influences its characteristics, and how the location has an effect on the relationships with other phenomenon. Environmental Systems Research Institute (ESRI), provides information on educational training, software products, and technical support through their educational Website http://edcommunity.esri.com. The significance of developing spatial skills and preparing students for jobs in the 21st century has prompted several school districts and states to obtain sites licenses for ArcGIS online (AGOL) which is free from ESRI, and have adopted GIS in their curriculum. The science methods course "SCI 396 Using Methods and Materials" taught at Ball State University, in the US is designed to integrate the basic elements of Geographic Information Systems (GIS) using ArcGis Online (AGOL). During these sessions, the students received hands-on experience and learned to navigate and use the GIS software through a series of exercises. The hands-on exercises are designed so that the students complete skills to develop a functional workflow, create a new map, examine the contents of a GIS database, execute queries for filtering data, and for performing spatial analysis, create buffer zones around existing GIS features, label GIS features (font, colour), and present graphics using map and legend objects. The innovate technology allows students to study topics such as the effect of pollution, changes in population and the consequences of urban growth, effect of deforestation and invasive species and the distribution of commodities. Using real world data, the students are able to visualise the problem at various scales. Thus, the pedagogy of geographic inquiry allows science educators to critically assess solutions for problems that continue to persist, but are examined through the GIS lens.

Back to programme

(A204) ASSESSMENT ON THE CONCEPTUAL LEARNING IN ELEMENTARY SCHOOL ELECTRICAL ACTIVITIES VIA MANUFACTURING SCIENTIFIC TOYS

Jian Yi LIN, *National Taipei University of Education*
Ching-san LAI, *National Taipei University of Education*

Abstract
The study targets at the assessment on the conceptual learning in elementary school electrical activities via devising scientific toys. The subjects are the 25 students in New Taipei city, Taiwan, and they are subject to 6 classes, each 40 minutes with the introduction of electrical concepts and hands-on assessment. In the beginning of the classes, the researcher motivates the students with the manufacture of scientific toys, proceeded by the lectures of scientific concepts including open and closed circuits, and batteries in series and in parallel. Then, the introduction for the operation of "the electrical irritating maze", a maze enclosed by electrical circuits, guides students to draw their own electrical designs of such scientific toy, to explain, and to validate the drawn design. Lastly, the students assemble "the electrical irritating maze", assessed by the researchers with troubleshooting tasks. This study analyzes the process that the students learned electrical concepts and assembled the toys via recording, semi-structure interview, and questionnaires. The results of this study includes: 1. Strong incentive in learning electrical concepts. By the rewards of the competition with their own made mazes, the overall learning achievement of each student was raised in the mutual-study process with their peers, and the students can build the electrical concepts on their own. The semi-structure interview disclosed that students will help each other in the maze assembly in order to launch and enjoy the competition derived from electrical concepts of interest. 2. Real-life application of electrical concepts It was justified that students were able to apply the learned concepts by the researcher's introduction of the operation of the scientific toys, the discussion among peers, the draw of the circuits design on the designed study sheets, the explanation of electrical terminologies including open and closed circuits, and batteries in series and in parallel, and the validation of the electrical circuit design. 3. The cultivation of comprehensive skills via the connection between the concepts and implementation of circuits. The researcher found that students completed the design and validate scientific concepts in relatively short time, and spent longer time in the assembly of the scientific toys. The results of questionnaire and interview revealed that the usage of tools such as wire stripper and screwdriver and the connection of circuits in three-dimensional space took more time for students to comprehend. It revealed that more comprehensive skills need to be cultivated during the process from learning to implementation of the concepts. 4. Troubleshooting skills improvement during implementation. After the assembly of the scientific toys, the researcher continued to test the students with both paper and hands-on quiz, and the students can write at least more than 3 causes, and find and solve the possible issues during the hands-on activities.

Back to programme

(A205) HIGH SCHOOL STUDENTS' LEARNING PROGRESSION IN CARBON CYCLE

Thanasak KONGKOEY, *Kasetsart University*
Boonsatien BOONSOONG, *Kasetsart University*
Jeerawan KETSING, *Kasetsart University*

Abstract

Learning progression has been recommended as a highly effective framework for curriculum, instruction, and assessment to scaffold children learning. Constructed from harmonization of scientific view and actual student's preconception, learning progression plays a key role in helping teachers to visualise learners' learning pathways, particularly in complex and non-linear concepts, like ecology. As shown in carbon cycling conception, this core concept in ecology represents holistic and specific function in which biotic, abiotic and human activity play in the flow. Nevertheless, the carbon cycling concept has been rarely investigated in terms of learning trajectories that individual learners travel for constructing knowledge. Thus, the purpose of this qualitative research is to find out the learners' prior knowledge in carbon cycle so as to elicit their common and alternative learning pathways, and to design hypothetical learning progression for carbon cycle. By addressing this issue, an open-ended question and diagram test was employed to thirty tenth graders in a high school in Bangkok. Three different standards and curricula: Next Generation Science Standard (United States), Basic Education Core Curriculum (Thailand) and school-based curriculum were adapted to be a framework for data analysis in the learning progression's upper anchor. Common misconceptions from literature and the students' prior knowledge were imposed for creating lower anchor and intermediate levels. Findings indicated that a common learning pathway in carbon cycle was that the students began their carbon form with carbon dioxide in atmosphere and it was utilised by plants for photosynthesis, and then devoured by animals and/or human creating carbon dioxide from respiration. For an uncommon pathway, we found that some children believed carbon dioxide dissolved in water and then turned into acid rain pouring into soil, and carbon was fossilized by nature and utilised by human creating carbon dioxide again without passing through plants and animals. In addition, the study revealed that most of the students possessed partial understanding and alternative conception about carbon cycling. For instance, the children understood that carbon transforming process happened only in atmosphere and biosphere, rather than in lithosphere and hydrosphere. And, many students thought plant uptaked soil carbon directly. According to the students' disparate pathways, the learning progression were designed into four levels, stratifying the participants from their sophisticated understanding of the concept. The pathways were then used for designing appropriate learning activities and assessment methods that aim to scaffold the learner learning. The findings from this study suggest that individual learners have their own level of understanding and learning pathway in constructing scientific knowledge. These pathways are not commonly in line with curriculum developers and/or teachers. Therefore, the design of curriculum and lesson plan that takes the student different conceptual trajectories into account may promote the learners' learning into a higher level or deepen their understanding of core science concepts, like carbon cycle.

Back to programme

(A207) GUIDED INQUIRY APPROACH: EFFECTS ON THE DEVELOPMENT OF CONCEPTUAL UNDERSTANDING, PROCESS SKILLS, CRITICAL THINKING AND ATTITUDES IN HIGH SCHOOL CHEMISTRY

Mark Anthony RUPA, *Division of Masbate, Department of Education, Philippines*

Abstract

This study determined the effects of the use of guided inquiry approach specifically Process Oriented Guided Inquiry Learning (POGIL) in the development of conceptual understanding, process skills, critical thinking and attitudes in high school Chemistry. Eight lesson-based activities in 'Gases' were developed and tested to Grade 10 students incorporating the learning cycle of exploration, concept formation and application using a quasi-experimental research design specifically the non-equivalent control-group design with pre-test and post-test. Four assessment tools were used to determine the effectiveness of guided inquiry learning in terms of conceptual understanding, science process skills, critical thinking and attitude. These assessment tools include: Conceptual Understanding Test in Chemistry, Science Process Skills Test, Critical Thinking Skills Test and Attitudinaire. The data gathered from the instruments were tallied, analysed and interpreted using descriptive and inferential statistical tools. To evaluate the effectives of guided inquiry learning in terms of developing students' conceptual understanding, science process skills, critical thinking and attitude, mean percentage score, performance level and t-test were used. The data revealed that in terms of conceptual understanding, the experimental group using guided inquiry approach gained after the implementation of the study compared to the comparison group who used traditional delivery method in teaching. The mean score for all the students in the experimental group for this study was 53.43% higher than the post-test mean for the comparison group. From the means of the two groups, a calculated t value of 8.5389 was obtained which exceeds the critical value of 1.667, therefore, the means were significantly different. The science process skills of the students exposed to guided inquiry learning had a mean score of 12.55 after the experimental intervention whereas those under the comparison group had a mean score of 9.6923. This indicates that the mean score of the experimental group was 29.49% higher compared to the comparison group. From the means of the two groups, a calculated t value of 5.2287 was obtained which exceeds the critical value of 1.667, so therefore the means are significantly different. The effect of guided inquiry approach in terms of critical thinking skills resulted to the experimental group having a mean score 15.65% higher than that of the comparison group. From the means of the two groups, a calculated t value of 2.80 was obtained which exceeds the critical value of 1.667, therefore, the means were significantly different. Overall, the experimental group performed better than the comparison group in terms of the development of conceptual understanding, science process skills and critical thinking skills. Guided inquiry approach also demonstrated a large improvement in the students' attitude in the experimental group with a mean difference of 0.39 compared to the slight decline in the students' attitude in the comparison group with a mean difference of -0.12. A guided inquiry learning model which is locally contextualised and therefore deemed appropriate for Filipino learners, coined by the researcher, "Exploration-Investigation-Concept Formation-

Application-Reflection" (EICAR), was evolved from the lessons learned on guided inquiry approach.

Back to programme

(A214) ROLE OF FORMATIVE ASSESSMENT IN STRENGTHENING PUPILS' UNDERSTANDING OF SIMPLE CIRCUITS BY A PROFESSIONAL LEARNING COMMUNITY

Mohamed Azhar MOHAMED NOOR, *Innova Primary School*

Abstract

A Professional Learning Team from Innova Primary School carried out an investigation to understand students' ability to communicate their understanding involving simple electric circuits. The team sought to uncover gaps in literature and surface prevailing alternative models that the students in the study have about simple electrical circuit. The team designed a science assessment that was administered to 219 Primary Five students for this purpose. From the initial investigation, the team confirmed alternative conceptions that students had on simple circuits fits into existing known model. In addition, the investigation revealed students had a lack of understanding of the working principles of a filament bulb. The team was further guided by the following research question: How can formative assessment be designed to improve students' abilities to communicate their understanding involving simple electric circuits? For this purpose, the team adopted a Lesson Study methodology to study the impact of an intervention lesson used to remediate poor conceptual understanding in simple circuits. The intervention lesson leverage on the use of formative assessment probe namely two-tiered questioning, Annotated Drawing and Brain Writing. Further, a unique coding scheme was designed for Content Analysis of the student's responses from this lesson. From the Lesson Study of the remediation lesson, it was observable that the students had significantly improved their proficiency in scientific communication of simple electric circuits. However, the team concluded that students' ability to communicate key ideas varied across the various ability groups Research by Black and William (1998) and others who have shown that formative assessment significantly improves student learning and is one of the most effective ways to close the achievement gap. The team's use of formative assessment allowed students to make their ideas visible to themselves as well as their peers and teachers. This helped students be more aware of their own thinking and more apt to communicate their understanding of simple circuits. An unintended impact of this investigation was the teachers reflected that they were more aware of their students' abilities and this has created a deeper awareness of looking from the students' perspectives. The PLT journey had raised the teachers' competency in the use of Formative Assessment for improved formal instructions. The investigation reaffirms the fundamental belief that the day to day classroom level assessment helps teachers in supporting their student by giving each student an active role in the design and implementation of investigations, in the preparation and presentation of student work to their peers, and in student assessment of their own work. Involving students in the assessment process does not diminish the responsibilities of the teachers It required teachers to help students develop skills in self-reflection by building a learning environment where students review each other's work, offer suggestions, and challenge mistakes in their daily work.

Back to programme

(A215) ASSESSING GRADE 11 STUDENTS' ABILITIES TO GIVE SCIENTIFIC EXPLANATION ABOUT THE ENDOCRINE SYSTEM: THE POTENTIAL SUPPORT OF SOCIOSCIENTIFIC ISSUES-BASED TEACHING FOR STUDENT'S CONSTRUCTING SCIENTIFIC EXPLANATION

Onnicha HONGKERD, *Kasetsart University*
Sasithep PITIPORNTAPIN, *Kasetsart University*
Pramote CHUMNANPUEN, *Kasetsart University*

Abstract

Nowadays, scientific explanation is increasingly recognised as a key role in science education valued in national standards. The learners should realise how claims to knowledge are judged by the scientific community. Even though the scientific explanation is one of the major goal in science education, it is not sufficiently emphasised in the science classroom. This study aimed to investigate the ability in making scientific explanation in each component of scientific explanation (claim, evidence, and reasoning) of the students. The participants of this research are 44 grade 11 students who studied in the first semester of academic year 2017. Students were encouraged to provide scientific explanation towards socioscientific issue "Animal sterilization" in learning unit of endocrine system based on Eilks model published in 2010. There are 5 main steps in Eilks model such as problem analysis, clarification of the science, refocus on socioscientific dilemma, role-playing task, and reflective activity for scaffolding the students to develop good scientific explanation. The students had developed the quality of scientific explanation through debate, role-playing and drama playing that were carried in this learning unit. Activities as above-mentioned are intended to promote the participation in persuasion between learners who hold different perspectives. Before instructional practice, students were assigned to complete the scientific explanation test which are divided into 6 concepts in the endocrine system learning units. The data generated from the tests were described by specific rubric based content analysis according to McNeill and Krajcik (2006). Survey findings revealed that most students have difficulty in providing appropriate scientific explanation. Considering individual scientific explanation component, students got the highest score in making claim whereas the scores in using evidence compared with reasoning are not significantly different. To clarify, 5.30 percent of participants were classified in a "good" level in making claim while none of learners are in this level in terms of using evidence and reasoning. Moreover, 28.03 percent of all students were counted to be as "fair" in providing claim; nevertheless, above 65 percent of all students were categorised in unsatisfied group in constructing every component of scientific explanation. The learners tend to just write a claim without providing any justification. They lacked the ability to identify what count to be claim, evidence, and reasoning. They also showed obvious weaknesses in using credible data to support their claims, for example, some learners used emotion, feeling or their previous experiences instead of scientific data. Similarly, demonstrating reasons to elucidate how their evidences support the claims is also challenging for these students. The findings of this research documented the noticeable problems about students' difficulties in constructing scientific explanation which occurred in actual science classroom. These provide the valuable guideline for instructional decisions as well as teacher's role in supporting the meaningful engagement in scientific explanation for high school students.

Back to programme

(A216) EXPLORING 10TH GRADE STUDENTS' DEDUCTIVE AND INDUCTIVE SCIENTIFIC REASONING IN BIOLOGY

Nalinee SONGCHA, *Kasetsart University*
Jeerawan KETSING, *Kasetsart University*
Mesayamas KONGSEMA, *Kasetsart University*

Abstract

Science educators consistently agree that advanced scientific thinking and reasoning are fundamental skills for living in the knowledge-based society, particularly in the 21st century. Recently, new generations are required to have argumentation skills to support their claims or recommendations that center on personal, social or global issues (OECD, 2014). Literature defines learners with deductive scientific reasoning are those who can set up possible explanations on a problem situation, design a sound experiment to test hypotheses, seek relationship or correlation among quantitative data, and formulate conclusion based-on empirical evidence. Additionally, the learners with inductive reasoning are able to look for patterns from data set, use analogy to relate new information with existing knowledge, and eliminate extraneous factors from main cause. However, literature conducted in classroom contexts often emphasizes scientific reasoning on either deduction or induction. There are a small number of studies focusing on both approaches of knowledge acquisition, especially in Biology. Ironically, this happens when biologists conceive a consensus view that natural world is understood through either hypothesis-testing or pattern-seeking.

Therefore, this study explored ways in which 42 tenth graders deal with biological-related problems using their scientific reasoning ability. Specifically, the study investigated whether or not the students were able to apply inductive and/or deductive scientific reasoning to solve the given situations. There were 7 situations in the open-ended test, four scenarios for deductive reasoning and the rest for inductive thinking. The test items were adapted from Lawson (1982; 2005) and Overholser (1993). According to Lawson (1982; 2005), deductive reasoning consists of four cognitive abilities: probabilistic thinking, control of variables, proportional thinking, and correlational thinking. For Overholser (1993), inductive reasoning involves enumerative generalizations, analogical comparisons, and eliminative causal reasoning. All problem situations were designed in line with the biological concepts taught previously. To explore students' reasoning ability, a class of tenth graders was invited to complete the biological situation-oriented test.

Findings from content analysis showed that the majority of grade 10th students have difficulty to identify appropriate variables for testing their hypotheses (73.81%). Many students struggle to formulate proper explanation from quantitative data (42.85%) or elicit correlation among the given variables (42.86%). In regard to inductive reasoning, the study revealed most children have a low ability in enumerative generalizations (83.33%). In other words, they cannot seek appropriate patterns from the dataset. Some students have some problems with analogical comparison (50.00%), in which they struggle to correlate new information with exiting experience. However, the study illustrated that the participants have a minimal problem with causal reasoning (28.57%). Most of the students can exclude extraneous factors from the actual one. These findings contributes to the field of science education by provoking teacher

educators to mindfully create learning experience that promote both deductive and inductive reasoning abilities in classrooms.

Back to programme

(A217) THE EFFECT OF A CAMP-BASED SCIENCE METHODS COURSE ON PRE-SERVICE TEACHERS' SELF-EFFICACY IN TEACHING SCIENCE AS INQUIRY

Elsun SEUNG, *Indiana State University*
Soonhye PARK, *North Carolina State University*
Myung-Ah LEE, *Indiana State University*

Abstract
The purpose of this research is to examine the effect of a science methods course combined with a summer camp on elementary pre-service teachers' self-efficacy in teaching science as inquiry. This research was guided by two questions: 1) How does a science methods course combined with a summer camp influence elementary pre-service teachers' self-efficacy in teaching science? 2) What experiences from the course influence their self-efficacy in teaching science? The science camp was offered to K-7 grade students as part of our intensive 4-week science teaching methods course (3 credit hours) over the summer. For the first two weeks, pre-service teachers engaged in various class activities and assignments in a university classroom setting to develop their knowledge, skills, and dispositions necessary to implement inquiry- based science lessons. For the next two weeks, they were assigned to one of three student groups (i.e., K-2, 3-4, & 5-7) and asked to teach camp participants in the assigned group. During the camp, the pre-service teachers were mentored by three experienced science teachers. We adopt a mixed-methods research design that involves the collection, analysis, and integration of both qualitative and quantitative data. Main data sources included Teaching Science as Inquiry (TSI) survey (Smolleck, Zembal-Saul, & Yoder, 2006) and interviews. Due to a small number of each cohort of pre-service teachers, data were collected for four consecutive years with 55 pre-service teachers. The TSI survey consists of five categories representing the essential features of inquiry-based learning (NRC, 1998) and we used only 34 questions from the personal self-efficacy dimension. The TSI survey was administered at the beginning and end of the course to pre-service teachers. Also, pre and post semi-structured interviews were conducted to investigate what experiences impact their self-efficacy in teaching science as inquiry. A two-tailed paired sample t-test was used to compare their scores on TSI before and after the course. The interview data were analyzed by using the constant comparative method. Data analysis reveals that pre-service teachers' personal self-efficacy improved significantly over the course. Total scores as well as individual scores for all five categories of inquiry features increased significantly between pre- and post-surveys. This finding was consistent with the analysis of the interviews. Main experiences that the pre-service teachers perceived as influential to their self-efficacy are: 1) Experience of developing and teaching inquiry-based lessons including meaningful hands-on activities, 2) Camp participants' positive reactions to their lessons and activities, 3) Structured opportunities for reflection and mentoring, 4) Overcoming a fear of science and/or science teaching, and 5) Improving knowledge in science content and educational theories. The findings of this study imply that a camp-based methods course engaged pre-service teachers in various experiences that contributed to their increased self-efficacy in teaching science. The camp-based methods course gives pre-service teachers more room to implement inquiry-based science lessons because they had less pressure to cover curriculum and prepare students for standardized tests. Overall, this study provides insight for teacher

educators who are interested in developing an informal context -based science methods course.

(A218) RESEARCH ON SCIENCE TEACHING IMPROVEMENT IN THE POST-PISA ERA --FOCUSES ON " EXPLAIN THE PHENOMENON SCIENTIFICALLY " IN AQUEOUS SOLUTION THEME

Chuan LI, *Beijing Normal University*
Lei WANG, *Beijing Normal University*

Abstract

The result of PISA (Program for International Student Assessment), a typical large-scale international assessment tool, which realizes the goals that the evaluation criterion is not changed by the course content and students' performance in different countries or regions can be measured by the same standard, has an important effect on the science education reform in different country or region. After knowing the students' performance in PISA (in the Post-PISA Era), it becomes a puzzle for many secondary or high school science teachers that how to integrate the curriculum standard and content with specific science topics in order to develop the competence standards of scientific literacy advocated by PISA. To resolve this problem, subject education experts from normal university, instructors and researchers in schools for teachers' advanced studies, and science teachers in secondary or high school, form a team to explore the theory and practice of the science teaching improvement in the post-PISA era. In this paper, the teaching theme is focused on aqueous solution in chemistry science, and the competence objective is to explain the phenomenon scientifically which is from the PISA 2015 framework. The definition in different level of the competence to explain the phenomenon scientifically is extracted from the summary description of the seven levels of proficiency in science in PISA 2015. According to this definition, an instructional design model (a tetragonal pyramidal model) is constructed, whose four basic elements in the bottom includes knowledge and experience, cognitive perspective, active task, and situational materials, and whose core element in the peak is the competence objective, for example, to explain the phenomenon scientifically, to evaluate and design scientific enquiry, to interpret data and evidence scientifically. In practice process, we integrate the aqueous solution content to this model, provide a series of challenging problems and set some prediction and interpretation tasks, in order to help students in the experimental class explain the phenomena whether the fruit and vegetable pesticide residues can be wiped out by shell powder, cleaning agent, white vinegar, baking soda, salt, from the cognitive perspectives such as macroscopic and microcosmic aspect, qualitative and quantitative view. Two rounds of teaching improvement and exploration are carried out in accordance with the improvement science paradigm. At the same time, we imitate the PISA open items to set the pre-test and post-test. After real teaching, students in the experimental class and the comparison class have those pre-and-post-test to check the improvement pots, which aims to verify the instructional design model for developing the competence to explain the phenomenon scientifically in PISA. According to the test results, the students' performance is higher in the post-test, and the improvement extent is better in the experimental class. In this study, we have tried to improve the science teaching in the post-PISA era and the attempt has been verified to success.

Back to programme

(A219) MULTI-FACETED MEANING OF SCIENTIFIC LITERACY FROM FIVE THEORETICAL PERSPECTIVES

Sophia JEONG, *University of Georgia*
Gretchen KING, *University of Nebraska–Lincoln*
David PAULI, *University of Georgia*
Cary SELL, *University of Georgia*
David STEELE, *University of Georgia*
J. Steve OLIVER, *University of Georgia*

Abstract
"I always loved science because there's always a right or wrong answer." Those were the words spoken by a Congressional District representative at the annual Science Day in 2017 Spring. The deterministic tone we heard in the representative's comment generally rings true with the public view of science. Many of us are familiar with the phrase: science is a way of learning about the natural world through observations and logical reasoning. This is a classic, textbook definition of science, which is repeated in various secondary science classes, and further asserts the notion that "science and technology have their own objective logic and reasoning to which society must adapt as best it can" (Irwin & Wynne, 1996, p. 1). The dissonance between the general public's consensus regarding the objective nature of science, and the misunderstanding and mistrust of science, is indeed intriguing. Problem. The debate about the misunderstanding and mistrust of science is nothing new. In 1996, Alan Irwin and Brian Wynne published a book entitled, "Misunderstanding science? The public reconstruction of science and technology." They explain ways in which the "public 'ignorance' is constructed" (Irwin & Wynne, 1996, p. 112). Furthermore, Shawn Otto, the co-founder of the U.S. Presidential Science Debates and author of The War on Science, gave a keynote address about ways to examine the mistrust of science, potential sources of mistrust, and to foster cross-sector collaboration to improve public trust in science and scientific institutions in the future (The National Academies Press, 2017). Otto stated, "There seems to be an erosion of the understanding of science and engineering among the public. People seem much more inclined to reject facts and evidence today than in the recent past. Why could that be?" Rationale and Purpose. How and why could the misunderstanding and mistrust of science be? Otto's rhetorical question continues to be an important problem that needs to be addressed. In previously cited work on the issue, metaphors such as wars on science were used, and the general public was portrayed as being ignorant. Critics of Irwin & Wynne's (1996) book criticised their framing of issue from a deficit-thinking model. In our paper, we aim to move away from the deficit-thinking model and the assumptions of Positivism. To this end, we posit that the pervasive assumptions about science stemming from Positivism can continue to deepen the public's misunderstanding and mistrust. Such tensions can be contributing factors to inadequate communication and misrepresentation of the nature of science. Therefore, the purpose of our proposal is to two-fold: First, we aim to conceptualise scientific literacy as a vehicle that can help ease the tensions and confront the issue of science mistrust and misunderstanding, by examining the multi-faceted meaning of scientific literacy from the following theoretical perspectives: 1) Positivism, 2) Constructivism, 3) Pragmatism, 4) Critical Theory, and 5) Post structuralism. In this process, we aim to achieve our second purpose, which is to facilitate an active polyphonic and dialogic process (Bakhtin, 2010) and have a meaningful conversation surrounding the issue.

Back to programme

(A220) LEARNING THE NATURE OF PHOTON AND QUANTIZATION ENERGY OF ELECTRON THROUGH A BOARD GAME

Ary NORSAPUTRA, *Mahidol University*
Suchai NOPPARATJAMJOMRAS, *Mahidol University*
Ratchapak CHITTAREE, *Mahidol University*
Thasaneeya Ratanaroutai NOPPARATJAMJOMRAS, *Mahidol University*

Abstract
In the beginning of modern physics, Max Planck introduced the concepts of quantum theory regarding the energy package as a photon. Planck stated that the energy is quantized as integers (n = 1, 2, 3, …), and the amount of energy is determined by its frequency. Over the times, quantum theory predicted that quantization energy of electron was an explanation of why those electrons shift from a shell to another shell of an atom. These formless concepts caused some difficulties to convey 1) the nature of photon and quantization energy to students; 2) the misunderstanding that students often categorize photons as a wavelength, and 3) the trajectory of a photon is along sinusoidal or straight path. Therefore, a learning tool is needed to simplify the concept to be easy to understand and interact directly with the learners. In this study, we propose an alternative way to learn the nature of photon and quantization energy through the board game. The game components consist of the main board, some coins as the representative of the photon, and cards. The game rules are arranged to present the photon roles and how the quantization energy (photon) make the electron transitions from one atomic energy level to another energy level. In order to study the effectiveness of the board game, this study focused on both quantitative and qualitative aspects. Seventy-two undergraduate physics education students were asked to play this board game as part of the classroom teaching. The game rules and components were introduced, and the students were advised to play the board game in a group. During the playtime, the students were given a reflection sheet to give their feedback on the board game. A set of multiple-choice questions (MCQs) was given to the students before and after playing the board game to investigate the students' understanding of the proposed concepts. The results revealed that students' test scores were significantly improved ($p = 0.000$). In terms of the board game, the students agreed that the board game, coins, and cards were the game components that helped them to learn the nature of photon and quantization energy. This was also implied in the overall students' responses that they gained the concepts of quantization energy (photon), absorption energy, the energy level of electron, and a free electron. Many students expressed their feeling on the board game which include "Playing board game is enjoyable and yet knowledgeable" and "The board game guides me to apply the concept of the quantization in a simple approach". Nevertheless, the board game still kept its role as a teaching tool by maintaining the game rules strictly based on the quantum theory aspects. It controlled the entire game components to show the nature of photon and quantization energy in terms of Max Planck hypothesis on blackbody radiation theory. In short, proposing the board game as an effective way to learn the nature of photon and quantization energy gave a new perspective of learning towards the matters which rarely visualise in daily life.

Back to programme

(A222) A POLICY ETHNOGRAPHIC APPROACH TO EXAMINING THE IMPLEMENTATION OF ENVIRONMENTAL EDUCATION POLICY IN TAIWAN

Ying-Syuan HUANG, *McGill University*

Abstract

This policy ethnography aims to investigate the development and implementation of Taiwan's environmental and sustainability education policies, and how these policies take up, mobilize, resist, or adapt local and global discourses on Education for Sustainable Development (ESD). Recognizing the importance of education in addressing global challenges, the United Nations (UN) declared 2005–2014 the Decade of ESD. The UN's goal was to highlight and address critical environmental issues around the world, such as climate change, biodiversity, and cultural diversity through education (United Nations Educational, Scientific and Cultural Organisation [UNESCO], 2005). In response to the global discourse on ESD, the Taiwanese government has been making earnest efforts to promote environmental education in all areas of learning. The Environmental Education Act, a new education policy, was promulgated in 2010 and went into effect in 2011. Aligned with UNESCO's vision for ESD, the goal of Taiwan's environmental education program is to enhance citizens' understanding and awareness of the world's environmental challenges, as well as to encourage active participation in environmental protection and sustainable development (Environmental Protection Administration [EPA], 2014). With the enactment of the Environmental Education Act, environmental education became mandatory in all K-12 schools in Taiwan. Government employees and school administrators are also required to complete at least four hours of coursework in environmental education each year. Moreover, the government has recruited and certified a group of Taiwanese environmental specialist educators (TESEs) to implement policies and curriculum related to environmental sustainability at local schools. As part of their work, TESEs assist the EPA in hosting professional development workshops on environmental education for schoolteachers and designing hands-on outdoor activities for K–12 students. They support teachers to integrate environmental and sustainability topics into their daily teaching. Policy ethnography, as an emerging qualitative research methodology, aims to explore policy implementation from the actors' standpoint by "studying the iterative relationships" between policy makers, policy, and education professionals (Griffiths, 2003, p, 163). This study uses a policy ethnographic approach and builds on a rich data corpus – documents, texts, interviews, field notes. Specifically, data sources include the UN and UNESCO publications and Taiwan's policy documents related to sustainable development and environmental education, two-round semi-structured interviews with 35 TESEs, and researcher's field notes during participant observations. All data were analyzed using thematic analysis and the constant comparative method. This work drew on Foucauldian conceptualization of discourse to understand how the UN's conception of sustainable development has emerged as a mainstream discourse and has gained its legitimate status to shape education around environmental sustainability worldwide. Governmentality was also used to examine the Taiwanese government and educators' vision, motivations, and strategies to promote sustainable living at local schools. Initial analysis has revealed that Taiwan's environmental education policies and related regulations are closely connected to the country's political positionality

in the regional and international arenas. Comprehensive findings will be presented at the ISEC conference. This study would be of general interest to the ISEC members because it illuminates effective policy models, curriculum initiates and pedagogical practices for environmental and sustainability education.

Back to programme

(A223) VALIDATING A CAUSAL MODEL OF MORAL OBLIGATION FOR PLANT CONSERVATION IN A NATIONWIDE GARDEN-BASED EDUCATION PROGRAM AMONG HIGH SCHOOL STUDENTS IN THAILAND

Pongprapan PONGSOPHON, *Kasetsart University*
William MCCOMAS, *University of Arkansas*

Abstract
The late His Majesty King Rama the ninth of Thailand and his daughter, HRH Princess Sirindhorn frequently expressed concern for the deterioration of plant diversity in Thailand. This concern gave rise to Plant Genetics Conservation Project (RSPG) that aimed to develop both botanical expertise and plant genetic resource (PGR) to support botanical conservation and lead to sustainable development. To raise awareness of the conservation of PGR, RSPG developed the Botanical Gardens in the Schools Program (BGSP). BGSP, founded in 1997, is a nationwide, primarily extra-curricular activity designed so students can learn about the biology, taxonomy, and benefits of plants by engaging in guided inquiry during which they grow, observe and study local plants. The goal of BGSP is that students will gain an understanding about botany but also come to appreciate the unique role that plants play in the environment. Each school chooses "a plant of study". The students were asked to study the plant thoroughly that could lead to the discovery of 'hidden potential' to further research and develop an innovation to benefit their community. The specific goal of the investigation reported here is to develop and validate a causal model of moral obligation for plant conservation related to participation in the BGSP activity. The study used a qualitative-quantitative mixed methods sequential exploratory design. A case study was conducted at four high schools that were awarded top honors for good practice from the RSPG. The findings of the case studies (which will be discussed in a subsequent report) were used in guiding the selection of variables used to build a hypothetical model of moral obligation for plant conservation to be validated in the quantitative study. The model ultimately comprised constructs that were expected outcomes of BGSP that might determine the moral obligation; environmental value, environmental belief, and basic knowledge and skill in botany. A validated survey focused on the desired variables was sent to and returned by the sample of 2,299 high school students from 56 schools nationwide who participated in BGSP activities. This survey explored the views on four constructs in the hypothetical model; environmental value, belief, knowledge and skill in botany and moral obligation. The findings indicated an acceptable model fit for the non-normal data applicable in this study ($X2 /df = 8$, RMSEA = 0.057, CFI = 0.973, SRMR = 0.034). The model suggests that environmental value had both direct and indirect effects on moral obligation via environmental belief. The strongest relationship was seen between environmental value and belief ($\beta=0.82, p<0.001$). The knowledge and skills regarding plant science has an effect on moral obligation only at a minimal level ($\beta=0.10, p<0.001$). The model may therefore be useful to explain the variances of environmental belief and moral obligation at 67 and 36 percent, respectively. The environmental belief is a mediator in the model. This confirmed the overall philosophy of environmental education as developed in BGSP. Also, this confirms Stern's value-belief- norm theory of environmentally significant behavior. This paper discusses theoretical and practical implication for environmental education in schools.

Back to programme

(A225) AN ANALYSIS OF KOREAN "SCIENCE INQUIRY AND EXPERIMENT" TEXTBOOKS' REPRESENTATIONS OF THE NATURE OF SCIENCE

Seungran YANG, *Seoul National University*
Wonyong PARK, *Seoul National University*
Jinwoong SONG, *Seoul National University*

Abstract
Developing students' understanding of the nature of science (NOS) has been a major goal of school science education around the world for several decades. South Korea recently reformed National Science Curriculum with an explicit emphasis on the nature of science. In addition, a new subject "Science Inquiry and Experiment" (SIE) was introduced as a part of grade 10 science in line with such a curricular emphasis. SIE is something that deserves academic attention, since it is the first curricular implementation in Korea to explicitly teach NOS (and science inquiry) as a separate school subject. In order to explore how NOS is represented in SIE, we chose to analyze science textbooks, since textbooks are a primary medium of NOS instruction that would influence teachers as well as students. This study focuses on the following research questions: (a) What aspects of the NOS are reflected in Korean high school SIE textbooks? and (b) How is the NOS addressed in Korean high school SIE textbooks? To this end, we analyzed seven SIE textbooks authorised for the 2015 revision of National Science Curriculum of Korea. The chapter titled "Science Inquiry in the History" was chosen for analysis in this study, since the curriculum document states that the key concept of this particular chapter is the nature of science. Erduran and Dagher's (2014) "Reconceptualized FRA-to-NOS" (RFN), based on the family resemblance approach, was used as theoretical ground for the analytical framework. In this approach, science is viewed as a cognitive-epistemic and social-institutional system. The cognitive-epistemic aspects encompass aims and values, methods, scientific practices and scientific knowledge, while the social-institutional aspects encompass social certification and dissemination, scientific ethos, social values, professional activities, social organisations and interactions, financial systems and political power structures. Content analysis of the chapters was conducted based on the 11 NOS categories. We carefully read the chapters, and then identified the sentences that included references to NOS and examined them to determine what aspects of science is being represented in each expression and how. Inter-rater reliability was established to 100 percentage agreement among the researchers through discussion. Findings showed that the NOS representations in the textbooks were mainly concentrated in the cognitive-epistemic aspects of science, while few expressions that addressed the social-institutional aspects of science were limited only to "social values" and "social certification and dissemination". In addition, the analysis showed that the NOS aspects were being addressed not only explicitly by providing authentic contexts through the history of science, but also implicitly through the replication of historical experiments. The overall results imply that while the textbooks are in general successful to the curricular goal of developing understanding on student's nature of science, diverse NOS aspects are represented not enough holistically and in a contextualized manner. Based on the analysis, some suggestions are made on effectively representing many aspects of NOS in a holistic manner and within the respective historical contexts.

Back to programme

(A226) DEVELOPMENT OF CONTEXT-BASED LABORATORY ACTIVITIES IN CHEMICAL REACTIONS USING LOW-COST LABORATORY KIT

Rona Lynne ABENOJA-FEDERIZO, *The National Teachers College*
Valera NESTOR, *Ateneo de Manila University*

Abstract
Chemistry education studies revealed several constraints like deterioration of students' content knowledge (OECD 2013) and undesirable attitude towards Chemistry (Tytler and Osborne 2012). Similar result was revealed from the study of Bennett et al. (2011) stating that Chemistry education is meaningless and irrelevant to students' lives. Cognizance of the need to bridge the gap between the content of Chemistry and students' daily life experiences ushered the researchers to pursue a study about developing context-based laboratory activities about chemical reactions. This study was also conducted to inspire chemistry teachers in the field to innovate activities in Chemistry. This study utilized descriptive method of research to present the results of the least-mastered topics in the departmental exam of General Chemistry for the last two consecutive academic years. All students who have taken the exam were considered in the descriptive analysis, which served as the basis for the selection of topic. From the results of the descriptive analysis, the least mastered topics were electronic structure of matter, periodicity, stoichiometry, chemical reactions and solutions. However, the topic "chemical reactions" was consistently analyzed as least mastered topic in the four-semestral periods, thus, selecting it as the topic for the development of CBLAs. The Context-Based Laboratory Activities (CBLAs) in Chemical Reactions alongside with the use of low-cost and locally available materials and substances were placed in a "Laboratory Kit". The CBLAs followed the generative model approach of Context-Based Learning (2014), which include Preliminary Phase, Focus Phase, Challenge Phase and Application Phase. The "Laboratory Kit" on the other hand contains the needed materials and substances in all the activities. Grounded from the learning competencies for chemical reactions, the CBLAs were developed and underwent validation from chemistry experts and science teachers who are currently in the field of teaching in terms of objectives; content and organisation/learning activities; language (clarity of explanation/approach and style; adaptability; and evaluation. The validators rated the Context-Based Laboratory Activities using Low-Cost Kit as highly favorable in all criteria of the activities. Furthermore, the readability of the CBLAs was also determined based on the Readability Formula by Talisayon (1983). It was found that all the activities have unclear words. However, the communication indices of all the laboratory activities were interpreted as "clear" and "completely clear" based on the communication index scale, thus, the clarity and appropriateness of the material can still be commendable. To further validate the viability of the CBLAs, students who were currently taking General Chemistry course performed all the activities. The students' evaluation of the objectives, materials and substances, procedure, and questions of laboratory activities using low-cost and locally available materials were perceived to be "highly favorable". Therefore, CBLAs with Low-Cost Chemistry Kit can be used as an alternative laboratory experiment in Chemical Reactions. The researchers recommend the utilization of Context-Based Laboratory Activities in Chemical Reactions using Low-Cost Kit in General Chemistry classes. Further evaluation of these activities can be explored in terms of

science process and laboratory skills developed by students after trying the activities.

Back to programme

(A228) A PROFESSIONAL DEVELOPMENT TOOL TO ENHANCE SCIENCE TEACHERS' THINKING AND REASONING ABOUT THEIR PRACTICE

Ravindran S., *Ministry of Education, Singapore*
Chor Yam LAU, *Ministry of Education, Singapore*
Pei Yun TAY, *Yusof Ishak Secondary School*

Abstract
In view of the essential role of teacher professional development, and the growing consensus of the inadequacy of traditional teacher training practices to meet the contemporary needs of teachers, there is great interest amongst researchers and policy makers in identifying effective teacher professional development approaches that may support teachers' efforts in educational reform. Ball and Cohen (1999) argue that rather than simply acquiring new strategies and approaches to teaching from decontextualized trainings, teachers need to learn in and around their practice. In this approach, actual contexts of teachers' on-going work or records and artifacts such as students' work, lesson and reflection notes form the resources that teachers can use to develop usable knowledge of content, students' learning, and teaching. This paper presents an exploratory study over two semesters in 2017, in the use of a teacher professional development tool, Content Representation (CoRe) within on-site teacher professional learning communities in a secondary school. A CoRe is a topic-specific representation of a group of teachers' shared knowledge or collective pedagogical content knowledge (PCK) about teaching and learning of that particular science topic (Loughran et al., 2006). The CoRe tool, which consists of 'big ideas' in the science topic and prompts to elicit pedagogical thinking about instruction, serves to support a group of teachers' discussion and testing of each other's pedagogical thinking and reasoning. Through this process, the collective PCK of the group of teachers becomes 'concretised' and captured. In this study, the researchers and professional learning team (PLT) comprising three teachers each semester, met during school-structured teacher professional development time to examine their collective thinking about teaching and learning of two topics in the lower secondary science curriculum - 'Particulate nature of matter' and 'Heat and its transmission' using the CoRe tool. Teachers collaboratively planned and developed lessons and reflected on the actual enactment of teaching specific ideas/concepts of the topic to their students. Data collection from this study include students' pre and post diagnostic probes and survey, students' work, and teacher observation and reflection notes. Findings from this study suggested that the CoRe tool when used for collective planning and reflection may provide valuable insights into teachers' thinking and classroom practice. Teachers were able to organise their lessons based on 'big ideas' in the topic to provide a more coherent learning experience for their students. Lessons were also specifically designed to allow students to confront and modify existing common alternative conceptions they may have in the topic through demonstrations, hands-on activities and real-world connections. Through a process of examining and testing their collective thinking about teaching and learning, and examination of their own students' work, teachers may begin to change their thinking and practices. The process of co-creating the CoRe for a specific science topic, using it to plan and conduct lessons and reflecting on the learning from the experience in teaching that topic through a team colloquium, offers an effective teacher professional development

approach that is school-based, on-the-job professional learning for science teachers that ensures relevance and applicability.

(A230) THE CO-CONSTRUCTION OF SCIENTIFIC MENTAL MODEL (CCSM) IN MOLECULAR GENETICS UNIT AMONG HIGH SCHOOL STUDENTS

Warithar RATTANAPANJAK, *Kasetsart University*
Pongprapan PONGSOPHON, *Kasetsart University*
Teerasak E-KOBON, *Kasetsart University*

Abstract
This project is an action research aiming to examine the effect of model-based learning on high school students' mental model in the unit of Gene and Chromosome. The target group was 29 Grade-12 students from a science high school in Bangkok Metropolitan Region, Thailand. The mental model was diagnosed by open-ended questions in which the students were asked to express their mental model in complementary to written explanation. The students' mental model was classified into four categories based on degree of congruence with the curricular model; no response, initial, synthesis, and scientific models. The learning process started with eliciting and visualizing students' existing mental model, asking them to share the model to their peers and apply the model to explain the given data. The students collaboratively evaluated the competing models and revised the existing model as needed. Last, they applied the revised model in other situations. To examine the effect of the intervention, the percentage of students holding a model in each category before and after the implementation were compared; the change in individual student's mental model was tested by Wilcoxon signed-rank test. Across the board, after the implementation, there were less students who did not respond to the questions while the number of students in the scientific model category increased. Most students, in varying extent, changed their mental model towards the scientific model. In the pre-test, more than 51 percent of students did not respond to the questions about DNA replication, protein synthesis and mutation. These concepts, per se, were dynamic and complex processes at molecular level. In contrast, 60 percent or more held the synthetic model in the concepts of chromosome, gene, DNA and their relationship in the pre-test. In post-test, the synthetic model was predominant in the concepts of the protein synthesis and mutation. This indicated big progress in their learning on these concepts; from no response to synthetic model. The scientific model was held the most among the students in the concepts of chromosome, gene, DNA and their relationship. Notably, the shape of chromosome during meiosis was the concept that most of students held synthetic model predominantly before and after the instruction (93 and 82 percent, respectively) and it was the only concept that they did not change their model ($p = 0.59$). The students had studied meiosis in Grade 10. The instruction could not challenge or elaborate their existing model. This project will share with the audience of ISEC 2018 various strategies and tips discerned from cycles of reflective practice to elicit and visualize students' mental model as well as how to enhance and use social interaction in co-construction of scientific model; creating conceptual conflict and tension, facilitating negotiation and resolution for the target scientific model.

Back to programme

(A231) INVESTIGATING GRADUATE STUDENTS' KNOWLEDGE STRUCTURES FOR SCIENTIFIC MODELS

Hsin-Yi CHANG, *National Taiwan University of Science and Technology*
Chin-Chung TSAI, *National Taiwan Normal University*

Abstract
Students' understanding of scientific models and modelling relates to how students learn science and engage in scientific inquiry. However, research indicates that students' understanding of scientific models can be naïve, regardless of their educational levels, including the eighth, ninth, and tenth grades (Treagust, Chittleborough, & Mamiala, 2002). Nevertheless, science curricula that explicitly engage students in learning about the nature of scientific models and in the process of scientific modelling can foster students' modelling knowledge (Schwarz & White, 2005; Schwarz et al., 2009). In this study, we investigated 30 graduate students' understanding of scientific models. These students had all enrolled in at least one course on the topic of history and philosophy of science or scientific modelling and learning, taught by science educators at three universities in Taiwan. We examined how well these graduate students developed sophisticated understanding of scientific models after taking at least one related course that addressed the topic of scientific models for science learning. Specifically, we employed structural assessment (SA) (Sarwar & Trumpower, 2015) to investigate the students' knowledge structures for scientific models. One approach of SA elicits participants' knowledge structures by asking them to draw concepts and relations graphically, similar to the concept mapping technique. This method also has the advantage that participants can represent their ideas in any manner of their choice, including text, symbols, diagrams, or graphs. Research has used this and related techniques to investigate teachers' knowledge structures for nature of science and scientific inquiry (Bartos & Lederman, 2014), or college students' knowledge structures in organic chemistry (Lopez, Shavelson, Nandagopal, Szu, & Penn, 2014). In this study, we asked the participants to visually represent their ideas about scientific models using a concept-mapping computer tool. As a result, 30 electronic drawings were collected and analyzed in detail. We identified that collectively the graduate students' knowledge structures for scientific models involved five dimensions: context of modelling, representations of models, functions of models, nature of models, and nature of modelling. Compared to previous frameworks validated via the surveying (Treagust et al., 2002) or interviewing (Schwarz & White, 2005) methods, the current study employed an alternative method to the verbal methods, i.e., the visual method, and found dimensions of modelling knowledge that have not been fully addressed in the previous frameworks, including the context of modelling and representations of models. Moreover, we found that, those participants whose knowledge structures involving nature of modelling (n=19) were more likely to also involve dimensions including nature of models and context of modelling in their knowledge structures. The types and trends of the graduate students' knowledge structures for scientific models will be presented. Ongoing and future studies include development of instruments to measure knowledge structures for scientific models for quantitative studies, and comparisons among different groups. These results can further inform us of how to design effective learning activities to enhance teaching and learning to promote understanding of scientific models and modelling.

Back to programme

(A234) FACTORS AFFECTING STUDENTS INTERESTS IN BROAD SCIENCE TOPICS

Derek CHEUNG, *The Chinese University of Hong Kong*

Abstract

Although interest is considered to be an important source of intrinsic motivation, few researchers have investigated the influence of personal and classroom factors affecting students' interest in school science. The present study was designed to address this gap in the science education literature, using science education in Australia, Denmark, Sweden, Finland, Hong Kong, Singapore, Thailand, and the USA as the research context. In PISA 2015, five questionnaire items were constructed to assess 15-year-old students' interest in five broad science topics: biosphere (e.g., ecosystem services, sustainability), motion and forces (e.g., velocity, friction), energy and its transformation (e.g., conservation, chemical reactions), the Universe and its history, and how science can help us prevent disease. The present study was guided by two research questions: (1) Are 15-year-old students interested in studying the five broad science topics? (2) What are the most important personal and classroom factors affecting students' interest in studying the broad science topics? To answer the first research question, an index of student interest in broad science topics was computed. The OECD average of the interest index was equal to zero. To answer the second research question, multiple linear regression analyses were used to analyse the data. Students' interest in the broad science topics was the criterion. A total of seven predictors of students' interest were included: students' science self-efficacy, enjoyment of learning science, instrumental motivation to learn science, epistemological beliefs about science, inquiry-based teaching and learning practices, environmental awareness, and students' participation in science activities. The means of the interest index for Australia, Denmark, Finland, Sweden, Hong Kong, Singapore, Thailand, and the USA were 0.04, 0.18, -0.09, -0.02, 0.25, 0.28, 0.60, and 0.05, respectively. This finding indicates that amongst these eight participating countries and places in PISA 2015, students in Finland showed the lowest level of interest in the five broad science topics. For example, only 27.2% of Finnish students reported that they are interested or highly interested in biosphere, whereas 63.7% of Hong Kong students are interested or highly interested in biosphere. Such a big difference should be a major concern to science educators in Finland. Multiple regression analyses revealed that the most important predictor of students' interest in the five broad science topics was their extent of enjoyment of learning science, followed by their frequency of participation in science activities. These findings were consistent across Australia, Denmark, Finland, Sweden, Hong Kong, Singapore, Thailand, and the USA. Surprisingly, the extent of implementation of inquiry-based teaching and learning practices in school was not a significant predictor of students' interest in the five broad science topics. One possible explanation is that the assessment items in the PISA 2015 project measured students' interest in studying the contents of five broad science topics rather than their individual interest in inquiry-based learning. The implications of these findings for designing valid and reliable ways to assess students' individual and situational interests in school science are discussed.

Back to programme

(A235) AN EMPOWERMENT EVALUATION APPROACH IN SHIFTING A SOUTH AFRICAN SCIENCE TEACHER TOWARDS AN INQUIRY-BASED PEDAGOGY

Umesh RAMNARAIN, *University of Johannesburg*
Nceba MAKHUBALO, *University of Johannesburg*

Abstract
Africa, the introduction of inquiry-based instruction has met with serious challenges, such as the poor training of teachers in the face of accelerated curriculum reform. Teacher training has been plagued with traditional "one-shot" approaches to professional development that are inadequate and do not provide teachers with opportunities for immediate and direct application of what they have learnt (Zakaria & Daud, 2009). In South Africa, a shortcoming of further teacher education programmes is that these programmes do not engage with the contexts in which teachers work and the level of the existing capacity (Motala, 2003). This study reports on an empowerment evaluation approach to teacher development. Empowerment evaluation is an approach whereby individuals can achieve self-determination in their practice. Empowerment evaluation commences with 'taking stock' with an assessment of what a curriculum does and does not do. This is followed with 'setting goals' where the evaluee agrees upon goals to achieve. In 'developing strategies', the evalue and evaluator agree on how credible data will be provided. Thereafter, they 'document progress', evaluate and improve. In this research, the researcher I worked with a Grade 9 Natural Sciences teacher in a rural school setting in South Africa. The goal was to empower the teacher in the introduction of an inquiry-based pedagogy informed by the 4Ex2 instruction model, which combines key components of inquiry instruction (Engage, Explore, Explain, Extend) with formative assessment and reflective practice integrated into each of the inquiry components. A case-study design (Merriam, 1998) was used. By employing the Electronic Quality of Inquiry Protocol (EQUIP) as a classroom observation tool, the researcher conducted six classroom observations, assessing the teacher on 19 indicators associated with inquiry spreading over four constructs: Instruction, Curriculum, Discourse and Assessment. In addition, stimulated recall discussions were used to enable the researcher the opportunity of seeing the classroom practices through the teachers' eyes. The discussions focused on the following: the objectives of the lesson, adequacy of background information, assumptions on which the lessons were based, investigative questions, plan/ design of the lessons, activities during the lessons, what was used to evaluate the lessons and how this was done and why, how error sources were identified during the lessons and what was done to correct errors and why? These discussions were underlined by the key facets of empowerment evaluation already described. The findings revealed that the deep reflection done by the teacher in the empowerment evaluation approach resulted in the teacher making significant changes to his lesson planning and classroom practice, and thereby shifting the teacher towards an inquiry-based pedagogy. The empowerment evaluation approach studied in this research thus offers a viable and sustained form of professional development that is likely to empower teachers in assessing, planning, implementing and evaluating what they do.

Back to programme

(A236) FACTORS INFLUENCING HIGH SCHOOL STUDENTS' ETHICAL REASONING ON THE APPLICATION OF MODERN BIOTECHNOLOGY

Onrumpa KUMNUANEK, *Kasetsart University*
Pongprapan PONGSOPHON, *Kasetsart University*
Uraiwan ARUNYAWAT, *Kasetsart University*

Abstract

Ethical reasoning is the ability of a person to make a rational decision on an ethical dilemma. Ethical principles provide a generalized framework within which particular ethical dilemmas may be analysed and resolved. They include respect for autonomy, justice, nonmaleficence, and beneficence. Given the rapid development of biotechnology, for example, genetic engineering, neuro-engineering, and personalized medicine, and the implications these raise for individuals and society, the students should be prepared by their teachers to actively participate and make informed decisions about their own and their society's future, providing bioethics education at all levels is necessary. Science teachers should inculcate moral value and ethics among students. They need to how their position themselves in ethical dilemma and what determine their ethical reasoning. The purpose of this study was to investigate the factors that influence ethical reasoning on the application of modern biotechnology. The selected explanatory variables included sex, ethical sensitivity, and conceptual understanding of genetics and genetic engineering. Data were collected from 191 high school students from 3 schools in Saraburi province, Thailand. These students had been taught classical and molecular genetics concepts before but never studied genetic engineering. The ethical sensitivity and ethical reasoning were measured by an open-ended questionnaire covering four controversial issues regarding the application of modern biotechnology; 1) Screening for Down's Syndrome, 2) BT cotton, 3) GM cows for Cystic Fibrosis patients, and 4) Golden rice for nutritious enhancement. These controversial issues represent the complex interaction and trade-off between health, economic, social benefits and the potential treats and risks. In each issue, the students were asked to describe their feeling or/and questions that first came up in their mind when encountered the issue. They were asked to decide whether they would go for or against the use of that biotechnology and justify for their choice. Their knowledge was measured by a multiple-choice concept test. The responses for the ethical reasoning were grouped into predetermined categories. To ensure consistency in the analysis, inter-coder reliably was established. To examine the relationship between the predictors and outcome variables, multiple regression was performed. The results show that the students had low level of conceptual understanding (M= 3.7, S.D. =1.9, scale 1:12) but they had moderate level of ethical sensitivity (M=1.8, S.D. =0.5, scale 1:3) and ethical reasoning (M=3.4, S.D. =0.7, scale 1:5). The students were more sensitive and used higher level of reasoning more in the issue of BT cotton, seen as the inference of microbe in nature and human consumption, than other issues. Gender and knowledge had no significant relationship with ethical reasoning. Ethical sensitivity had weak relationship with ethical reasoning ($r = .174$, $p < 0.05$) and could explain the variance in the outcome variable only by 3 percent. There must have been some relevant variables omitted from the hypothetical model. The findings of this study provide compelling evidence for science teachers on the determinants of ethical reasoning that should be created in science classroom.

Back to programme

(A238) SOCIO-SCIENTIFIC ISSUES IN INDONESIA SCIENCE TEACHING

Faisal SUDRAJAT, *Seoul National University,*
Sonya N. MARTIN, *Seoul National University*

Abstract
In Indonesia, science teaching in the context of socio-scientific issues (SSI) has not been widely implemented in the schools due to limited access to resources for teachers about how to integrate SSI topics in school science. Furthermore, SSI is not explicitly described in the national science curriculum. Nevertheless, SSI is relevant in Indonesia because new government policies in science education seek to improve students' scientific competencies and literacy, especially helping students to have more critical perspectives about the environment. To introduce SSI topics at the upper secondary school level, we created an SSI-based lesson plan (LP) and assessment instrument (AI) that teachers can use to structure and implement SSI topics in Biology. In this presentation, we explain our process for developing our SSI-based LP and AI, including the overall structure and components. We also discuss the Indonesian Biology curriculum and we describe common features of Biology textbooks and describe how effectively they can both align to SSI-teaching approaches. Finally, we provide context for explaining the importance of using this SSI tool to teach Biology in Indonesia. To create our instruments, we first reviewed the literature about SSI curriculum design. We evaluated various models of SSI-based instruction and adopted some common features for our tools, including: (1) use of a complex, socially relevant issue as a starting point; (2) involving students in critical thinking, (3) and emphasizing attention to scientific, ethical, and social dimensions for each issue. We then identified significant issues in Indonesia that have wide social and environmental impact and that are frequently reported in national mass media. From these, we selected three issues to explore at different grade levels: forest fires, negative effect of drugs on people and environment, and Biotechnologies. We examined the National Biology Standards and nationally published textbooks to identify alignment to curriculum defined basic competencies and we also identified all concepts that are relevant for exploration from an SSI perspective. Using this information, we developed a lesson-plan format and assessment instrument that could be used by teachers to target these basic competencies and SSI related issues. The structure of our LP consists of 5 components: (1) general information about the topic, (2) instructional objective, (3) learning activities, (4) learning resources, and (5) assessment objectives. The assessment instruments were created using open-ended question items directly tied to the science content covered in the SSI content. Our tools will be piloted with pre-service biology teachers to support their design of their own SSI-based lessons and assessments for use in the secondary biology classroom. We believe these tools will support teachers to better implement SSI related content in Indonesian schools. We believe this pedagogical approach can promote meaningful development of students' scientific competencies and literacy while also increasing students' awareness of the social, ethical, and environmental issues. We raise questions about the need for future research in this area.

Back to programme

(A239) USING INTEREST-BASED LEARNING TO MOTIVATE DISINTERESTED STUDENTS IN THE LEARNING OF SECONDARY SCHOOL PHYSICS

Kam Kheun HONG, *Changkat Changi Secondary School*
Shi Ru NG, *Changkat Changi Secondary School*

Abstract
BACKGROUND OR CONTEXT: Two classes of Secondary Three combined Science Physics classes were combined into one as one of the classes has less than ten students. The two teachers adopted a co-teaching strategy. Majority of the students are not motivated as observed during lessons and are generally weak in the subject as seen from the summative assessment results. In Term 2, a differentiated instruction approach was adopted with the class being divided into two groups according to their level of readiness. The low readiness students did even worse in terms of lesson engagement and performance. Thus in Term 3, an interest-based learning and collaborative learning pedagogy was used with the combined class of students being divided in teams of 3, with a mix of high, medium and low ability students. GOALS OF THE STUDY: The goals of the study is to assess the effectiveness of Interest-Based Learning to generate interest in classroom lessons and to increase engagement through Collaborative Learning. Carefully thought-out lesson materials that uses their prior knowledge and highlights linkages between new concepts with preceding ones to show connections and developments of concepts hopefully motivates students to want to learn Physics. A lesson engagement survey based on the PETALS Engagement Instrument was conducted to assess the engagement level of the students. A comparison between the summative assessment scores at the end of Term 1 and Term 3 will be made to see any significance of this approach on students' performance. METHODOLOGY: The interest-based learning pedagogy is to use novelty and variety to make the students curious and to look forward to the classroom lessons as they have no idea how the day's lesson is to be conducted. Lesson formats, worksheets, activities, assessments were varied to create wonder among the students. Collaborative learning is to encourage peer teaching and learning through hands-on activities in simple experiments, conceptual understanding-focused worksheets and problem-solving questions. Immediate feedback is given to correct misconceptions and to provide guidance to improve or cover gaps in their understanding.

FINDINGS & DISCUSSION : Results from a lesson engagement survey based on PETALS Engagement Instrument showed positive indication of engagement and learning. A comparison of the students' end of term summative tests scores showed improvement for all students except two who happened to be in the same team. Informal conversations with students confirmed their increased engagement during class lessons and also greater involvement in learning. It was also observed that the higher ability students were actively involved in helping their peers with their learning. Students are on-task, discussing and working on the problems or the worksheets.

IMPLICATIONS & SIGNIFICANCE: The above approach was conducted over Semester 2 in teaching the Section on Waves which covers General Properties of Waves, Light, Electromagnetic Waves and Sound. The plan is to continue to use this approach for the subsequent topics and to study its effectiveness.

Back to programme

(A242) COORDINATING POLICY REFORM WITH EXISTING TEACHING PRACTICE: A LONGITUDINAL INTERVIEW STUDY OF TEACHERS' RESPONSES TO NATIONAL TESTING AND GRADING IN SCIENCE EDUCATION IN YEAR 6 IN SWEDEN

Malena LIDAR, *Uppsala University*
Eva LUNDQVIST, *Uppsala University*

Abstract

The release of major reforms has implications for teachers' practice and makes teachers reconsider how they teach. Recently an increased centralized control was introduced in Sweden. Along with a new curriculum, grading and national tests in science education were introduced in Y6 in 2012/2013. However, after three years of the new regime of national testing, a new government was elected, and the national tests in science education ended. Consequently, science teachers teaching in Y6 was faced with a situation of quick changes in the curriculum which govern their space for professional judgements. The aim of this study is to investigate the consequences of reform changes on teachers' teaching and assessment practice, with a focus on the introduction and ending of national testing in science. We have interviewed 10 experienced Y6-science teachers from a diverse set of schools exploring their habits of teaching four times during four subsequent years, 2013-2016, starting from the introduction of grading and national tests. In all of the interviews we had an overarching focus on the teachers' views on science and science education and their enactment of the reforms and how they had an effect on teaching practice. In this exploration we build on John Dewey's work considering teachers' talk about their everyday practice as expressions of their habits of teaching and dispositions to act when approaching reforms. The analyses show that the teachers in different ways are struggling to balance local teaching autonomy with external assessment-driven reform. In the first years it was striking that almost all the teachers accepted the reforms as a positive element in their professional work. Despite that the national tests were described as time consuming, most of the teachers found the tests inspiring and helpful in their teaching practice. Several teachers took elements from the tests and actively adapted them, over time, to their local contexts. Reform elements that operated in this way were 'assessment matrices' and 'locally devised marking of national tests'. These policy elements provided a degree of in-built flexibility whilst also retaining core features of the external reform. However, analyses from the last interview round showed that teachers, who had talked about the tests as inspiring them to work in new ways, no longer actualised the content in the tests in their valuations about important science content. One implication drawn from this research is that to successfully implement reforms presupposes that teachers get time to make the reform continuous with their teaching habits. If reforms, in this case national tests, have not fully been coordinated with existing habits, it will not be regarded as a problem that they end. The extended time over which teachers develop and shift their responses to reforms also has implications for the piloting and evaluation of reforms. Many policy makers are driven by short term, often political, timescales. They are keen to demonstrate whether a reform has 'worked' or not. The message from our study is that in the complex context of schooling evaluation activities need to extend over several years.

Back to programme

(A244) REVEALING THE COMPLEXITY BEHIND PROCESS OF TRANSFORMATION OF CONTENT KNOWLEDGE

Elizabeth MAVHUNGA, *Wits University*

Abstract
Introduction: Teaching Pedagogical Content Knowledge (PCK) to science pre-service teachers is an intricate process. One of the reasons is the realization that it is no more sufficient to refer to PCK without defining the level of its location. One of the widely shared recommendations in the literature is to support the development of science pre-service teachers' PCK with reference to specific topics, and also to consider such knowledge a core practice to be passed on (e.g. Abell, 2008; Aydin, Demirdogen, Atkin, Uzuntiryaki-Kondakci, & Tarkin, 2015). However, its teaching to pre-service teachers has however, remained obscure and fuzzy. The purpose of this study was to illuminate to full view, the complexity in the emergent structure when components of topic specific PCK interact among each other as pre-service teachers plan to teach a topic, and the kinds of teacher tasks generating such complex interactions. Method: The study employed a qualitative in-depth analysis method. Data were Content Representations (CoRes) accompanied with expanded lesson outlines of 15 pre-service teachers who were learning to plan well-reasoned chemistry lessons in chemical equilibrium in a methodology class. The pre-service teachers were in their fourth and final year of study towards a first degree in teaching (B Ed). The objective of the course was to improve the quality of PCK in core chemistry and physics topics, one of which is chemical equilibrium. This version of PCK is considered located in a topic and called Topic Specific PCK (TSPCK). The development of PCK in chemical equilibrium was based on an intervention that entailed learning the competence to pedagogical transform content knowledge from reasoning through a topic from the perspective of the five content specific components of TSPCK which are: Learner Prior Knowledge; Curricular Saliency; what is difficult to understand; Representations and Conceptual Teaching Strategies. The analysis involved extraction of episodes that exhibited component interaction. Findings and Discussion: The results revealed the emergent structure in which topic specific PCK components interact among each other to be interwoven, and in some cases, a combination of linear and interwoven interactions co-existing in a lesson planning segment. The interwoven structure contained multiple topic specific components and was linked to more richer teacher responses with clear connections across different elements of the same concept, thereby transforming concept explanations into a non-threatening story. The most sophisticated component interactions emerged from teacher tasks on descriptions of a lesson sequence and a summary of a lesson. Recommendations in this study include strategies for making pedagogical transformation of content knowledge more accessible.

Back to programme

(A245) HIGH SCHOOL STUDENTS' CONCEPTIONS ON CELL DIVISION: THE DEVELOPMENT OF STUDENT'S CONCEPTIONS THROUGH MODEL-BASED LEARNING INTEGRATED WITH CREATING MULTIMEDIA

Virayuth KHAMDI, *Kasetsart University*
Chittamas SUKSAWANG, *Kasetsart University*
Teerasak E-KOBON, *Kasetsart University*

Abstract
Alternative conceptions are considered to be the main obstacle for students' learning in science. Several research studies over the past ten years revealed that high school students hold misconception in complex contents especially in biology conceptions, such as cell structure, a cellular process, genetics, plant, and animal development, which rely on knowledge of molecular level. These conceptions are untouchable directly with their hands and unseen with their naked eyes. It might be the dominant factor that hinders students' understanding in these abstract concepts. Similarly, mitosis and meiosis cell division conceptions occur in microscopic level, therefore, students may have difficulty to recreate them as concrete matter in mind as well as construct the concepts and leads them to misinterpretation. Model-based learning (Rea-Ramirez, 2008) is one of the instructional approach that shows effective performance in the development of students' conceptions. While, integrating multimedia, such as video, stop motion, as the instructional media also promotes students' understanding in complex concepts as well. The objectives of this action research aimed to study effects of model-based learning integrated with creating multimedia on students' conception on cell division. The participants included 48 (18 males and 30 females) tenth-grade students in a science-mathematic classroom from a school situated in Bangkok, Thailand. To explore students' understanding of this concept, the Cell Division Concept Test was employed before and after the instruction. The test consisted of six open-ended questions, focusing on cell cycle, mitosis, and meiosis cell division, and to be interviewed according to the results of the test. The data of students' conceptions was analysed to percentage and categorised by Haidar's (1997) framework. The results showed that before instruction most of the students hold specific misconception (SM) in the topics of cell cycle (89.58%), mitosis cell division (47.92%) and meiosis cell division (56.25%). They struggled to explain the mechanism of these processes related to the DNA amount, changes of chromosome number in mitosis and meiosis, genetic recombination events during meiosis and differences between mitosis and meiosis processes. There were no students hold sound understanding (SU) in these topics. This finding indicated that students may had little understanding of the fundamental concepts of biology that form the building blocks for further study and leading to difficulty in understanding a complex system in cell division. Surprisingly, after the instruction the students had sound understanding on cell cycle (62.42%). In addition, most of them had partial understanding (PU) in the topic of mitosis cell division (50.00%) and had partial understanding with specific misconception (PUSM) in the topic of meiosis cell division (81.25%). The findings suggested that the use of model-based learning integrated with creating multimedia influenced to the students' scientific conceptions. Moreover, creating multimedia by students also enhanced their understanding on the cell division process. However, some students still had specific misconception on DNA amount and changes of chromosome number during mitotic and meiotic cell division.

Back to programme

(A246) EXAMINING FACTORS CHALLENGING PRE-SERVICE SCIENCE TEACHERS' EXPECTATIONS ABOUT INCLUSIVE SCIENCE EDUCATION

Da Yeon KANG, *Seoul National University*
Sonya N. MARTIN, *Seoul National University*

Abstract

The shift to inclusive education is widely practiced in international contexts. To meet the educational needs of individual students, there has been consistent research trying to train general teachers to be prepared for implementing appropriate inclusive education. However, it was found that there were still considerable challenges which limit in-service teachers to practice teaching in their content area. Especially in science, due to the complex terminology and experiments, science teachers are not willing to have Special Education Needs (SEN) students in their classes. Unfortunately, teacher education programs in Korea do not offer any content-specific course about special education. Science teachers at the secondary level also have limited opportunities to engage in real teaching practices where they can meet real SEN students. To support science teachers to fulfil inclusive science education, we designed a semester-long teacher education course focusing on science. The course included a series of activities offering pre-service science teachers experiences inviting them to consider different issues related to inclusive education. Activities included a lecture by a parent with child with disabilities, a site visit to a special education school, and a full-day science fair for SEN students. We collected data from 11 pre-service science teachers participating in this experiential learning course. The teachers participated in pre- and post-course interviews, group interviews after each activity. They also wrote autobiographies, which helped them reflect on their experiences and revisit their beliefs for five times during the course. While participating in the experiential learning course and reflecting on their experiences, we found the teachers expanded their understanding about SEN students. They also improved their knowledge about inclusive science education practices. Pre-service science teachers became generally more positive about inclusive education compared to before. Specifically, we found that teachers expanded their ability to see beyond a students' disability and to instead see each SEN student as a science learner. In addition, we found that this course helped to professionalize our teachers as they began to imagine themselves in their future classrooms and to consider their roles and responsibilities for teaching science to all students, regardless of ability. However, we also found unexpected changes as several pre-service teachers reported that as their understanding about SEN students increased, they became overwhelmed and more concerned about how they would be able to implement inclusive science education practices in the future. We explore what factors impacted on pre-service teachers' beliefs about inclusive science education and we offer implications about how to transform teacher education programs to better support teachers to be prepared for teaching science in inclusive settings. We also suggest ways to transform Korean schools to better support in-service teachers to be able to maintain their positive views about inclusive science education once they enter the teaching profession.

Back to programme

(A247) THE EFFECT OF ARGUMENT-DRIVEN INQUIRY ON HIGH SCHOOL STUDENTS' SCIENTIFIC ARGUMENTATION

Wilaiwan SONGSIL, *Kasetsart University*
Pongprapan PONGSOPHON, *Kasetsart University*
Boonsatien BOONSOONG, *Kasetsart University*

Abstract
Scientists and lay people use argumentation to make good judgment in making informed decision at all times. They make claims, based on observable evidence, and clarify with justification of the evidence as relevant to the claims. They must deal with rebuttal claims, pointing to other evidence that counters the evidence for the previous claim. They generate, verify, communicate, debate and modify the explanation. This study aims to examine the effect of argument-driven inquiry on high school students' scientific argumentation. The subjects were 72 Grade 10 students from two schools in Bangkok, Thailand. They participated in five ADI-oriented lessons in the Unit of Life and Environment, Biology, over the course of two months. According to the features of ADI, the teachers selected and presented an issue to provoke students' thinking. The teachers exemplified scientific argumentation. The students practiced making verbal and written argumentation in a safe and respectful learning atmosphere and got instant and continued constructive feedback from their teacher and their peers. They were asked to reflect upon their argumentation and learning process. The students' argumentation skills were measured by Test of Scientific Argumentation (TSA) in which the students read three dilemma stories; climate change, forest road cut and community forest management. In each story, students were prompted to generate a claim and a warrant, evidence, counter argument and supportive argument. For each component of argumentation, the response was given a score point from 1 (poor) to 4 (excellent) using scoring rubrics. The total score for TSA was 42 points (16 points/story). To compare the means before and after the implementation, a paired sample t-test was used. The results indicated the post-test score of overall scientific argumentation (31.76, S.D. = 2.65) was statistically higher than that of the pre-test (27.11, S.D. = 3.30) at $p < 0.01$, so was each and every component of argumentation. Consistently across the issues, pre-test and post-test, the means of the evidence used to prove the argument and the counterargument were less than that of other components. The students might have found it more challenging to find evidence to support their claim and rebuttals. This implied that the teachers should encourage students to spend good deal of time on the adequacy and quality of data gathered. They should give advice to the students to be critical on the data; what data were useful, how to collect, manage, interpret the data. The teachers should ensure that the piece of supporting evidence be dearly tied to the claim using appropriate scientific principles as well as the use of multiple lines of evidence. Even the invention could develop students' scientific argumentation, the change was minimal and the post-test was 64 percent. Prolong engagement in ADI and training on metacognition strategies would help students master scientific argumentation.

Back to programme

(A249) TEACHING SCIENCE WITHOUT WORDS: A CASE STUDY INVOLVING SLOW LEARNERS IN MAURITIUS

Mohun CYPARSADE, *Mauritius Institute of Education*

Abstract

In the Republic of Mauritius, pupils who fail their examinations at the end of primary schooling are admitted in Pre-Vocational schools. These pupils, who are only 11-13 years old, are of below average ability and many of them lack motivation for formal schooling. They have poor abilities in the language of instruction (English) which is not their mother tongue, so they perform badly in most subjects, including in science. They also have a lot of disciplinary problems which render their schooling more problematic. As they cannot get employment at this age, they are admitted in the pre-vocational stream. This stream is mandated to provide an alternate route for their education and these students may integrate the main stream after four years spent in this stream. After their schooling in the pre-voc stream most of them integrate the vocational training in wood work, metal work, agriculture, plumbing and so on. The curriculum designed for students in the pre-vocational schools includes Literacy, Numeracy & Problem Solving Skills, Life Skills and Livelihood & Trade Skills. Though students are offered a diluted curriculum in the pre-vocational schools, there still exists a language barrier that needs to be addressed. A lot of innovative strategies have been trialled but still there is some additional effort to be put by the educational authorities to make it successful in terms of competencies developed by these students, progression to main stream and their employability. The main problem lies in the assessment as it is mostly based on written papers in English. Through this study, there was an attempt to find out how science can be taught through the minimal use of English language. Concepts in 'Water' and 'Electricity' were taught through the use of ICT resources and Role Play, with ample related and relevant visuals. Post-tests, worksheets and classroom observations using checklist in several such classes show that there was an improvement in the understanding of the chosen concepts and the language barrier was overcome to certain extent. The findings also show that science can be taught successfully to very low ability students with the minimal involvement of the language of instruction, provided an appropriate blend of strategies and resources are used. The findings of this study can be very useful to educators in their planning and delivery of lessons to low ability learners as these activities are specifically designed for this category of learners. They can also be very useful to parents and learners when doing follow up work at home. Curriculum writers can use such elements of good practices to prepare activities that would enhance understanding of concepts by low ability learners. Teacher trainers may use certain elements of good practices in their teacher education programmes. Even policy makers may recommend trialled innovations in policy documents for the benefit of educators and learners.

Back to programme

(A250) TEACHING AND LEARNING OF 'DYNAMICS' THROUGH A SOCIO-CONSTRUCTIVIST APPROACH: A CASE STUDY OF CONCEPTUAL CHANGE AT O-LEVEL

Mohun CYPARSADE, *Mauritius Institute of Education*

Abstract

Physics is perceived as one of the most difficult subjects in the secondary school curriculum. Sometimes even the well-educated people know little about science. This societal phenomenon has constantly been observed through conversations with students, teachers, parents and other people who are not directly involved in physics education. Even some higher ability students recognise this fact that learning of physics is more demanding than other subjects. Some science education specialists believe that in general, teaching of physics is still conducted very superficially with limited resources and strategies. The link to real life phenomena is missing in many cases. Given that there are many abstract concepts involved in the teaching and learning of physics, teachers are encouraged to do their best to make learners understand physics concepts despite the inherent difficulties in its teaching. In this study, the researcher attempts to teach 'Dynamics' at O-level using the socio-constructivist approach and to gauge the level of conceptual change achieved among learners. There are two groups of students involved in this study and both have similar characteristics in terms of the ability level, age (14-15 years) and they are all following the same curriculum prescribed by the Government of Mauritius and the same syllabi prescribed by the University of Cambridge Local Examinations Syndicate. The classroom facilities are the same in all the classes involved and even the educators have almost same characteristics in terms of qualifications, training undergone and experience acquired in teaching. Concepts taught are "friction, action-reaction pairs, Force = mass x acceleration and resultant force'. The control group has been exposed to teaching of Physics concepts in Dynamics using innovations such as ICT and Role Play. Even the experimental group has been exposed to the same teaching and learning process by the researcher. The only difference in the experimental group is that lessons have been developed in a socio-constructivist set-up and all activities have been conducted through collaborative learning strategies. Post-tests, classroom observations using checklist and focus group discussions have been carried out to gauge the difference in conceptions by learners when exposed or not to the socio-constructivist set up during the lessons. Even the educators of these students have participated in focus group discussions to reveal their teaching-learning experiences using the socio-constructivist set-up. Findings tend to show that those students who were exposed to the socio-constructivist set-up during teaching-learning experiences have progressed more than those who were not exposed. There are both qualitative and quantitative indicators to make this claim. The findings of this study have implications for teaching – learning activities in the classroom by the educators. Teacher educators can infuse the findings in their programmes. Curriculum material writers are recommended to pick elements of good practice and infuse them in the textbooks and workbooks prepared for learners. Even policy makers can officially recommend the package developed under this project study due to the advantages that it has demonstrated.

Back to programme

(A251) CHILDREN'S CRITICAL LITERACY SKILLS ON SCIENTIFIC ENVIRONMENTAL PROBLEM SOLVING

Mijung KIM, *University of Alberta*
Suzanna WONG, *University of Alberta*

Abstract
With an increasing challenge of socioscientific and environmental issues in the current society such as climate change and energy saving buildings, decision-making and problem solving skills in complex problem contexts become pivotal aspects of scientific and critical literacy practices for the 21st century. Much attention has been paid to students' critical thinking and problem solving in science classrooms, however, the focus has been given to content-oriented scientific problems which are often isolated from lifeworld situations. Much of school science teaching has remained in traditional contexts, being compartmentalized and disconnected from other dimensions of knowledge. Such approaches have resulted in the lack of scientific knowledge application in the examination of real world problems. Another challenge of students' problem solving activities in today's science classrooms is that students rely much on information available in web space without understanding how in/valid internet resources could be. This raises pedagogical concerns about critical thinking/literacy and decision making skills in lifeworld socioscientific and environmental problem solving. There have been studies on critical literacy practices in the digital world, which looks into children's skills of interpretation and evaluation on information shared in web space such as a study of children's abilities to evaluate fake news done by Stanford Study. Critical literacy skills have become essential in socioscientific and environmental issues, yet, there have not been many studies on children's critical literacy practices and skills, especially critical evaluation on web-based information in science education. The study is concerned about a) how children make meaning from what scientific information being presented online, b) what are critical literacy practices children needed to engage with when understanding scientific and environmental issues, and c) what are some ways teachers can use to teach these critical skills in science classrooms. As this issue is timely in today's classrooms, this study looks into possible ways of implementing the teaching and learning of critical literacy skills to develop children's socioscientific and environmental problem solving in science classrooms. 23 children in a Grade 5-6 combined class in an elementary school in Western Canada participated in this study. Children's problem solving activities were video/audio taped and classroom artifacts (children's writings, drawings, designs, etc.) were collected for data analysis. Thematic coding (open, axial, and selective coding) was employed to understand classroom interactions and critical literacy aspects throughout problem solving processes.
In our presentation, we will focus on two of our preliminary findings, which suggest that teachers' questioning skills played an important role in scaffolding their students' critical literacy learning in a science classroom. Secondly, critical literacy and environmental problem-solving skills can be co-constructed with teachers and students together in an inquiry problem solving project. Based on the findings, we will further suggest pedagogical strategies to develop children's critical thinking and decision making skills in/through interdisciplinary curriculum contexts.

Back to programme

(A252) TEACHER'S DILEMMA: ALLOW QUESTIONING IN LESSONS?

Erkan POLATDEMIR, *Hwa Chong Institution*

Abstract

Probing students' understanding through effective questioning is considered to be an impactful teaching method as it promises to stimulate higher order thinking skills, generate insightful discussions and empower students to learn on their own. Taking into account of students' cognitive readiness and establishing a culture of thinking in lessons are non-negotiable for its effectiveness. Walsh and Sattes (2011) argue that when implemented successfully, quality questioning can, in fact, be indistinguishable from formative assessment and feedback. One of the well-known teaching practices to implement effective questioning is to observe wait time (or think time) strategies. Rowe (1986) found out that when teachers observe Wait Time 1 (pausing 5-6 seconds after a question is asked) and Wait Time 2 (pausing slightly longer after a response is received), students achieved a great deal of learning. This spurred interest in thinking time and obtaining thoughtful responses from students which is desired because such responses indicate that a deep understanding is being formed. Dillon (1988) summarizes this point by saying that "our interest should not be in the production of the correct answer but in the answer the student produces". The challenge is how to infuse a thinking culture into every lesson, obtain thoughtful responses from students and make this state of learning sustainable. Despite its significant contributions into students' learning, effective questioning does not receive enough attention in real-time classroom contexts due to somewhat reasonable limitations such as time constraints to complete a curriculum, not wanting to embarrass students, not wanting to lose teacher's authority figure (Walsh and Sattes, 2005) and insurmountable task of activating System 2 thinking processes (Kahneman, 2011) in a heavily loaded school timetable. Hence, a different lens may be needed to provide science teachers with practical solutions for their day-to-day classroom experiences so that effective questioning becomes a natural state of teaching. In this paper, a functional way to achieve this goal is proposed: keeping regular reflection notes ("journal") after science lessons and building up a repertoire of thinking questions which could generate insightful discussions. First of all, details about how to regularly keep such a journal – amid busy schedule of teachers – together with thinking questions will be shared. Based on the entries from such a journal, how inquiries raised by students led to successful learning moments within the context of physics concepts will be illustrated. Successful learning moments are meant to spark students' curiosity and interest in physics, to encourage them to share their understanding and to provide thoughtful responses. Queries such as how could massless photons have momentum, why single slit was not necessary when a laser pointer was used as a light source in demonstrating Young's Double Slit Experiment, why photoelectrons have a range of kinetic energies, why accelerated charged particles emit electromagnetic radiation will be analysed. Lastly, implications for teaching and learning especially how effective questioning could lead to active student learning environments will be discussed.

Back to programme

(A253) EFFECTIVENESS OF INTELLECTUAL STANDARDS TO DEVELOP CRITICAL THINKING SKILLS IN SEC 3 CHEMISTRY STUDENTS

Kian Seh LOW, *Temasek Junior College*
Zhe Ming Shawn NEO, *Temasek Junior College*
Yuan Shun HO, *Temasek Junior College*
Miaohui TNG, *Temasek Junior College*
Xuanjun LI, *Temasek Junior College*

Abstract
The research study aims to investigate the effect of using Intellectual Standards during day-to-day teaching on students' critical thinking, as demonstrated by the quality of student writing and gain in test scores. This study also investigates the students' perceived effectiveness of the intervention, and sentiments towards the continued usage of Intellectual Standards. This study was performed on 161 students in Temasek Junior College's Integrated Programme Year 3 (equivalent to Secondary 3 students, or Grade 9), about 15 years of age, taking Chemistry as the compulsory subject. These students are from six different classes, with three teachers involved in the research study teaching two classes each. The intervention was conducted within the topic of Chemical Bonding. For the quantitative study, the subtopics of metallic and ionic bonding were used in the pre-test and the post-test, but the intervention of teaching with explanations incorporating Intellectual Standards was used only in the subtopic of covalent bonding, conducted after the pre-test. This was done to ensure that during the post-test, improvement in answers is likely due to an internalization of the Intellectual Standards taught in a different subtopic, and no standard model answers that could improve answer quality could have been furnished due to the intervention. The results of pre-test and post-test were analysed by means of the t-test, and the students showed an overall significant gain in test scores (at 5% significance level) as a cohort of 161. Further analysis by class showed that the gain in test scores was greater in some classes than others, and these classes were perceived to be academically weaker. This was subsequently triangulated via the quality of student answers in the pre-test and post-test. There is visible improvement in the way the answers were structured and presented for some of the students who showed significant gain in test scores. A perception survey was conducted with the cohort, to study if the gains in test scores are correlated with the mean Likert score for the responses. Teacher effect would also be discussed. From the qualitative comments in the survey, it could be inferred that for the students who displayed general positivity to the use of Intellectual Standards, they would have appreciated it and likely benefited more if Intellectual Standards were introduced much earlier when they were in Year 1 (i.e. Secondary 1 or Grade 7) so that they have greater familiarity with Intellectual Standards before the teaching and learning of the content matter for the subject. The study also included a Focus Group Discussion with three identified groups of respondents to the survey: students with very positive, neutral, or very negative responses, with the aim of acquiring greater insights into how the teaching of content matter using Intellectual Standards can be improved to better engage all students.

Back to programme

(A255) SECONDARY SCHOOL STUDENTS' CRITIQUE OF SCIENCE RESEARCH POSTERS

Yann Shiou ONG, *Pennsylvania State University*
Richard DUSCHL, *Pennsylvania State University*
Julia PLUMMER, *Pennsylvania State University*

Abstract

While science education researchers acknowledge scientific argumentation comprises both construction and critique practices, existing literature emphasises constructing arguments. This study addresses this gap by examining critique practices in the science classroom. Student/teacher discourse during a poster review activity is examined between groups in two learning environments: student-centred critique (Class A) versus teacher-centred critique (Class B). The study research question is: To what extent are accountability, authority, Problematization, resources – the guiding principles of Productive Disciplinary Engagement (PDE) (Engle & Conant, 2002) – addressed? Class groups each carrying out a student-designed research project over three semesters (29 weeks) are compared. In the first semester (5 weeks), Class A received students' shared critique instruction and practised critiquing work using scientific soundness criteria (i.e. students critiqued literature and their peers' research proposal using the critique criteria). Class B was 'business as usual' (i.e. students reviewed literature by summarizing, and the teacher critiqued students' research proposals). Each class comprises two groups of three students and a science teacher. The poster review activity took place in the middle of the first semester. The analysis examines critique discourse from groups A1 and B1 who both reviewed the same science research poster. Video segments of group talk were transcribed and analysed. Groups' written reviews were also reviewed to clarify talk, where necessary. The analysis sought evidence for the PDE principles: 1. Authority - Who challenges the ideas presented? 2. Disciplinary Accountability - Are students' ideas held accountable to valued epistemic criteria? 3. Problematization - Are the critiques potentially of concern to scientists? and 4. Resources - What resources are provided to help students with critique? Findings suggest students in both groups challenged ideas and critiqued the poster, demonstrating authority for students. While A1 spontaneously looked for errors in the poster, B1 considered positive aspects and only looked for negative aspects after the teacher intervened. Both teachers held students accountable to their own ideas by requiring they justify proposed ideas. As for disciplinary accountability, both groups considered the poster's communication of methods description and explanation; a concern for scientists communicating claims. Interestingly, B1's critiques were mostly based on the communication criterion following their teacher's guidance to use such criteria. Apart from communication, A1 saw a problem with methods not answering the research question. Thus, A1's critique demonstrated disciplinary accountability and problematization. In terms of resources for critique, both teachers modelled critique to groups by providing their critique of the poster, which occurred more frequently with B1 (thrice) than A1 (once). Teacher critiques with B1 reinforced the communication criterion, while teacher critique with A1 was based on the scientific soundness criteria. Also, A1 demonstrated instances of utilising the scientific soundness criteria, suggesting the criteria served as a resource. Findings suggest taking a critical stance to scientific claims is not natural to

students. While teachers held students accountable to justifying ideas, they do not necessarily emphasize epistemic criteria. However, evidence from A1 where students were guided to use critique criteria suggests such resources improve critique practices in the science classroom.

Back to programme

(A256) DEVELOPMENT OF TWO-TIER DIAGNOSTIC TEST TO IDENTIFY STUDENTS' UNDERSTANDING IN WORKING PRINCIPLES AND APPLICATIONS OF BIPOLAR JUNCTION TRANSISTORS

Thasaneeya Ratanaroutai NOPPARATJAMJOMRAS,
Institute for Innovative Learning
Myat Noe KHIN, *Institute for Innovative Learning*
Suchai NOPPARATJAMJOMRAS, *Institute for Innovative Learning*
Ratchapak CHITTAREE, *Institute for Innovative Learning*

Abstract

The bipolar junction transistor (BJT) is a three-terminal semiconductor device which is a basic of the development of many modern electronics. BJT is a fundamental electronic device for students to study the control and power electronics in electronic engineering programmes. A BJT, the first type of transistors, is mainly used as an amplifier (to boost or amplify the electrical signals) and an electronic switch in modern digital circuits. In addition, BJT is the most important functional element in all power conversion applications and still be used for specific purposes in many electronic appliances. Thus, the working principles and applications of BJT are important for electrical and electronic students in both analogue and digital electronics. Students in undergraduate electrical and electronic engineering programmes have learned the BJT working principles and applications in many courses such as microelectronics course as a preliminary course of advanced electronics, control and power electronics courses. Most of the students particularly try to memorize the BJT circuit configurations and related equations even though they do not understand the principles of BJT. Students have also faulty thought that this is an effective form of learning. Furthermore, students do not perform well for applying the BJT in electronic circuits. The objective of this study is to develop the diagnostic test (two-tier) to identify students' understanding in BJT structure, BJT basic operation and biasing, the states of operation and applications of BJT. Each item consists of a) multiple choice questions used to check the ability of students in specific areas and b) open-ended questions used to elicit more information, reasons for the corresponding answer in part (a), of students' understanding. The item-objective congruence (IOC) was used to check the validity by three experts who are professors in electronics at the tertiary level. The students' response to the test were analysed quantitatively for the multiple choice questions (Part a) and qualitatively (thematic approach) for the open-ended questions (Part b). The participants were 50 students who had learned the working principles and applications of BJT in the previous semester. The overall results showed that almost 50 percents of the students still having problems in the understanding of working principles and applications of BJT. In addition, results also revealed that some misconceptions in BJT basic operation such as 1) the students thought that the collector current of an NPN transistor remains the same according to the relation of base current and collector current (current gain, $\beta = I\_C/I\_B$), 2) the collector current flows through the collector resistor in cutoff condition because there has collector supply voltage, 3) the needed value of base input voltage for BJT to operate as an opened-switch is 0.7 V, and 4) the collector current has reached maximum and independent of the base current in breakdown region were held by this group of students. The results of this study will be used to develop the effective teaching and

learning approach and instruments to promote the level of students' understanding in BJT topic.

Back to programme

(A257) TEACHERS' PERCEPTIONS ON CHEMISTRY LABORATORY AND USING GREEN CHEMISTRY AS 21ST CENTURY LABORATORY LEARNING IN SECONDARY SCHOOLS

Mageswary KARPUDEWAN, *University Science Malaysia*
Yvonne KULANDAISAMY, *University Science Malaysia*

Abstract
Laboratory is a necessity for learning science like chemistry as it facilitates development of problem solving skills and learning of abstract concepts occur in more tangible manner in a laboratory setting. The purpose of this study is to examine the views of chemistry teachers on the importance of chemistry laboratory, how do chemistry teachers perceive their current chemistry laboratory in secondary schools, how green chemistry labs can be used in place of the current chemistry labs to bring about changes of what teachers' perceive and can green chemistry labs be implemented in secondary schools today. A qualitative method with open ended questionnaire were employed to gather teachers' feedback. A quantitative method of survey based on five-point Likert scale was also conducted on evaluation on green chemistry experiments. These questionnaires were administered after teachers conducted several green chemistry experiments. Findings of the study which involved 57 chemistry teachers (N=57) on the evaluation on green chemistry experiments exhibited an overall min of 4.16.The qualitative analysis data revealed that chemistry laboratory were crucial for students in understanding chemistry concepts and creating a meaningful learning. Teachers perceive their current chemistry laboratory as being restricted due to factors such as time constraint to complete many experiments in the syllabus, chemical reagents and apparatus that were insufficient, only selected experiments were conducted due to availability of the chemicals as cost to obtain them were involved and experiments did involve chemicals that were hazardous and teachers had difficulties carrying them out especially for big group of students. Green chemistry labs were seen to bring about positive changes in what teachers' perceive in terms of safer lab was assured for the teachers and students, reduction of cost in obtaining chemical, students dealt with much greener substances that were more environmental friendly and easily obtained substance that were readily available and much familiar as they were closely related to daily life, increase students interest in carrying out experiment as it was more benign and also created awareness of sustaining the environment. Implementation of green chemistry labs in schools were supported by the teachers as it reduces the cost of purchasing chemicals, increased students' interest to study science, students and teachers are less exposed to hazardous substances, the content were in line with the syllabus and students would learn much better as they were related more to daily life. On the other hand, teachers felt that these green chemistry labs should be absorbed into the syllabus and needed the cooperation of the Ministry of Education for its implementation as teachers are not able to move on their own implementation as they need to adhere to current curriculum which were very exam oriented and rigid. This study outlines green chemistry lab as a new teaching pedagogy for laboratory learning in schools. It is a good source for teachers to present their views on the current chemistry laboratory and would shed some light to the curriculum developers on ways to improvise or make some changes which is relevant that meets the need of the 21st century learning.

Back to programme

(A258) HANDS-ON LEARNING EXPERIENCES FOR PRIMARY SCIENCE STUDENTS: A STUDY ON THE EFFECTIVENESS ON LEARNING PHYSICAL SCIENCE

Pei Ling GO, *Ministry of Education, Singapore*

Abstract

Inquiry-based approach has always been known to be an effective pedagogy in the teaching of Science. Teachers wondered if this approach could be further enhanced to improve the effectiveness of student learning of physical science. According to Jennifer Ann Jocz, Junqing Zhai & Aik Ling Tan (2014), it was found that indeed inquiry or guided inquiry approach does contribute to primary students' interest in Science. However, students are even more interested when they are repeatedly exposed to the hands-on activities with situational interest, that is, activities that has real-life application. Another factor for students' increased interest in Science is the provision for peer discussion during the lessons. This is supported by Tajularipin Sulaiman , Wei Hui Suan , Saifuddin Kumar Abdullah (2009) where it is found that good Science teaching should be constructivist in approach, where new knowledge is constructed on old knowledge through hands-on approach that are interactive. In this study, it aimed to find out the effects of hands-on experiences on (i) students' perceptions on the learning of physical science and (ii) students' ability level in learning science. A qualitative and quantitative study was carried out to look at the adequacy of this approach as far as learning accomplishments and inspirations are concerned. Those who participated in this study were 68 primary 5 students from 2 classes, high ability and low ability, with two teachers in a primary school in Singapore. To collect the quantitative data, 2 tests were administered to the participants at the start and the end of the study. The pre-test consisted of an open-ended question to assess the participants' prior knowledge before the intervention. Participants went through a 10-week module on building a lighted house where they had to set up electrical circuits for the house. A parallel post-test will then be administered. To measure students' motivation towards Science learning, SMTSL questionnaire developed by Huang and Tuan 2001, Tuan and Chin 1999, 2000, Wu and Tuan 2000 was used. This survey comprises of 35 items on a 5 point Likert scale. It measures self-efficacy, active learning strategies, Science learning value, performance goal, achievement goal and learning environment stimulation. Analysis of Pre-test and Post-test, motivation results A t-test analysis will be used to analyse the tests results and only students who have completed both tests are included in the data set. In this study, the dependent variable, which is the improvement of results after taking the difference between post and pre- test represented the actual improvement or knowledge gain from the hands-on learning experience. Positive value represented an improvement, which means knowledge gained. Similarly, negative or zero data then indicated no improvement. The means and standard deviations of the pre-test and post-tests will be compared across the 2 groups. The study is ongoing and the data will be collected at the end of October.

Back to programme

(A259) GRADE 10 STUDENTS' EFFICACY ON LEARNING AND INNOVATION SKILLS

Sirawut CHANACHAI, *Kasetsart University*
Akarat TANAK, *Kasetsart University*
Chomdao SINTHUVANICH, *Kasetsart University*

Abstract

Learning and innovation skills consist of four sub-skills: Creative thinking skills, Critical thinking skills and problem solving, Communication skills and Collaboration skills. It is an important skill that every citizen must have to be able to live smoothly life in the stream of rapid changes in data, information and technology in the 21st century. Previous study suggested that the quality of science education could contribute and develop these skills. However, the teaching style in Thai science classrooms still emphasised on lecture. Teachers normally transferred the content from the book to the student without opportunities to practice by themselves. Recent research has studied the development of each sub skill separately. The study on the development of these skills in holistic view is required. The aim of this research was to explore students' efficacy on learning and innovation skills as a basis for development of learning activities to enhance students' learning and innovation skills. The subject was 26 grade 10 students who studies in a science enrichment program in a public school, Thailand. The instrument used in this study was a two-part questionnaire. The first part was five point rating scale on a set of items about their efficacy on learning and innovation skills, and second part is open-ended questions. The questions consist of a situation for provoking student thinking skills. This tool was validated by three experts. The findings showed that students' efficacy on learning and innovation skills were at a moderate level. When considering skills separately, the collaboration skill was a high level. While other skills, creative thinking skills, critical thinking skills and problem solving, and communication skills, are at moderate level. This was consistent with the information obtained from the open-ended questions. All students could identify the cause of the problem, determine the reliability of various sources of information that appears in the article, and provide solutions to problems without the various views of thought. Students identified only one main cause of the problem, and relied on evidences related to science, or reliable person. This reflected that students' critical thinking and problem solving skills lack substantially. Moreover, students also lack creative skills to design something new and different from the original. When considering creative thinking skills through the design of new food menu for diet person, it was not as diverse as it should be. There are only four menus from 75 students. This might be the result of the emphasis on teacher-centered rather than student-centered. Students did not engage with an authentic, ill-structured problem that requires further investigation or research. Active learning that students must be doing things and simultaneously think about the work done was required. It can enhance their higher order thinking capabilities. The data obtained from this survey research will be used as a basis for development learning activities or innovation to promote the prior skills, and encourage some skills that students have less.

Back to programme

(A261) A CASE STUDY EXPLORING SCIENCE TEACHERS' JOURNEY INTO THE PEDAGOGICAL DESIGN AND PRACTICES OF AUTHENTIC ASSESSMENTS AT LOWER SECONDARY LEVEL

Josephine CHANG, *St. Joseph's Institution*
Jerry TAI, *St. Joseph's Institution*
Kah Yan WONG, *St. Joseph's Institution*
Jun Hien CHONG, *St. Joseph's Institution*

Abstract

Ever since its conceptualisation by Wggins (1993) and Stiggins (1987), authentic assessments have become a staple of the assessment system. With the focus by Singapore's education system to infuse 21st century learning skills in schools, there is renewed effort to implement alternative assessments such as authentic assessments which focus on real-world tasks and open ended problems in contextualised setting. This is to be done in tandem with traditional summative assessments. As science education is moving into integrative learning of concepts, skills and practices that supports the workings of real world, the teaching and learning of science must also incorporate engagement in such relevant tasks in addition to inquiry based instruction. Since assessment and instruction are intrinsically linked, assessments must also move towards performance based with the use of wide variety of approaches to capture the multi-faceted aspects of solving real world problems. Authentic assessments fulfill such criteria as they take the form of performances and all sorts of open-ended tasks which are contextual in nature. Exemplary authentic assessment allows students to demonstrate knowledge and skills that are worthwhile during their application of knowledge in completing or solving the authentic tasks. As majority of schools are still in traditional assessment settings using them for summative purposes, the developing of authentic assessments in science can be onerous and challenging. There is a need for teachers to examine deep into the pedagogical design of the authentic assessment, so that it will be reliable and valid in assessing the learning of essential concepts and skills. The implementation of the authentic assessments requires time and effort thus there is a need to have strategies in place to manage the balance of traditional expectations in the curriculum with the authentic assessments activities. This case study examines the beliefs, practices and concerns of lower secondary science teachers over a two-year period during which two authentic tasks were designed and implemented. Elements of Erikson's (2007) concept-based three-dimensional curriculum and instruction approach is used to design the unit plans which incorporate the overarching concepts and enduring, essential understandings that helps in crafting an authentic performance tasks. McTighe & Wiggins's backward design is used to align the assessment criteria to the authentic tasks. The tasks were implemented for over 300 lower secondary students over the two-year period. Interviews and questionnaires were administered to uncover the teachers' learning and experiences as they went through the designing and implementation of the authentic assessments for lower secondary level. The study explores how the teachers use authentic assessments, the problems they encounter, the strategies used to overcome learning challenges and the students' responses to the authentic assessments. Future classroom research may build upon this study to inform teachers on the effective management of the design and execution of authentic assessments and pedagogy, while overcoming the constraints of a traditional assessment setting in schools.

Back to programme

(A262) EXPLORING SCIENTIFIC ARGUMENTATION SKILLS OF GRADE 12 STUDENT IN THE UNIT OF HORMONES

Methanon SANGACHAT, *Kasetsart University*
Ekgapoom JANTARAKANTEE, *Kasetsart University*
Wirasak FUNGFUANG, *Kasetsart University*

Abstract
Argumentation is a once gigantic goal of science education because the knowledge of science is derived from the rational argumentation of the scientific community. Scientific arguments encourage students to understand the reasoning, finding credible evidence, objecting to empirical evidence. Promoting students' argumentation skill in the science classroom would lead the students to be the meaningful learner and scientifically literate person. However, learning in Thailand mostly focuses on lecturing. This instruction leads the students to lack the opportunity to learn by themselves and to collaborate with other students; especially exchanging ideas together. The lack of discussion, resulted Thai students are not familiar with scientific argumentations skill.

This research aimed to explore 39 grade-12 students' scientific argumentation skills in the topic of "Hormone". The instrument used in this was a scientific argumentations test which comprised of two parts. The first part was an article about the use of stimulants in athletes. The second part was the argumentation skill questions. It consisted of 4 questions for measuring 5 factors of scientific argumentations skill: claim, warrant, evidence, counter argument and supportive argument. The data was analysed by content analysis.

The findings showed that the majority of grade 12th students had little scientific argumentation skills. In making claim and warrant, all students make claims about the use of athlete stimulants. However, 51 % of students use emotions to express their reasoning. Only 13 % of students that they use scientific reasons in warrant issues. Surprisingly, in the factor of evidence for supporting the claims, 20 % of the students cannot provide any evidence to support warrant and 26 percent of the students provide evidence for supporting their opinion but warrant that topic by using emotional without scientific evidence. In the same way, the others two components including supportive arguments and counter arguments. The results are obtained in the negative way. Because more than half of the students cannot reason in the other argument and most of the students use emotions to argue to the opponents.

According to the observation result in this research, was founded the traditional teaching cause insufficient in the skill of scientific argumentation which Thai-student remain observe this problem. The main problem of the traditional teaching system is not focused on the class activity of student so the old system can be founded the lacking of the cognitive constructivism, social constructivism, and scientific argumentation student. The primarily data obtained from this study could be used as a basis for the development of scientific argumentation skills for my students and for the development of learning management tools to promote students scientific argumentation skills.

Back to programme

(A265) EXPERIENTIAL LEARNING & ENVIRONMENTAL LITERACY

Liyun WONG, *Pioneer Primary School*
Ahmad FAIRUZI, *Pioneer Primary School*
Norhisham SAADON, *Pioneer Primary School*

Abstract
This paper examines the use of experiential learning to develop students' environmental literacy. Recent studies suggested that environmental issues is a concern for future generations. As science and the environment is one of the key domains in the Singapore Science Curriculum Framework, it is essential to develop environmental literacy in our students. Environmental literacy is defined as the capacity to perceive and interpret the relative health of environmental systems and take appropriate action to maintain, restore or improve the health of those systems. Hence, raising students' awareness and motivating them to be more proactive in environment conservation is critical. The sample size for this study were 50 primary school students. Customised horticultural workshops, teacher-led workshops on designing and building biodiversity trails were conducted to build up students' capacity. We also collaborated with external agencies such as National Parks Board and Mitsubishi. The Environmental Literacy Test (ELT) was adopted to measure the four dimensions of the students' environmental literacy; knowledge, attitude, sensitivity and concern. In this study, only 3 dimensions; knowledge, attitude and sensitivity is examined. The team also experienced the challenge of building a physical eco-garden in the school. The students artifacts collected includes commentaries, detailed descriptions on biodiversity, contributions towards BIOatlas. Through the artifacts, students displayed environmental knowledge beyond the standard syllabus requirements. A high level of environmental attitude was observed through the students influencing their peers to be more inquisitive in learning more about their environment. The number of students visiting the eco-garden increased and more students presented on environmental topics during school assemblies. Pre and post-surveys were conducted on 18 random students to measure sensitivity towards the environment. Descriptive analysis showed that students have high degree of sensitivity relating to the environment. However, there is no significant increase in the environmental sensitivity of the students after the workshops. Furthermore, they have low to moderate levels of environmental sensitivity towards issues relating to importance of biodiversity. Although the students attended several biodiversity workshops, planned and carried out the hand-on experience of building a eco-garden, it did not lead to a significant increase in their environmental sensitivity levels. This might be due to the level of understanding in issues relating to biodiversity. Perhaps more deliberate thought has to be placed into the biodiversity content planned for the students in our existing curriculum and further studies can be conducted. The programme, however, had increased the level of students' environmental knowledge and improved environmental attitudes among the students. In conclusion, the learning of science and the environment can be expanded outside of the curriculum. Experiential learning activities provide opportunities to observe the ethics and attitudes students display towards the environment. This serves as an alternative platform to inculcate positive ethics and attitudes explicitly.

Back to programme

(A267) THE MENTAL MODEL ABOUT CELESTIAL SPHERE OF 4TH YEAR SCIENCE STUDENT TEACHERS

Paniwad SENKED, *Khon Kaen University*
Jiradawan HUNTULA, *Khon Kaen University*

Abstract

Astronomy is one of humanity's oldest sciences to study the sky and learn about the changing of the position of star on the celestial sphere. However, there are few tools to help student understand the concepts of astronomy. Following, Ruangsuwan and Arayathanitkul (2009), the study of a low-cost celestial globe for hands-on astronomy, found that students had some problems and needed more explanations to define the position of the North celestial pole (NCP) to draw the ecliptic and define the vernal equinox. Therefore, this research armed to study about the students' mental model on celestial sphere; celestial coordination and the motion of celestial sphere, the fundamental concepts in astronomy. We adapted and developed the celestial globe to support students' understanding about position of the NCP and the ecliptic by using the paper plate to demonstrate the ecliptic. In addition, we created a new set of model to teach the relation between the latitude of the observer and the altitude of the Polaris. The activities consisted of six inquiry lessons based on the hands-on activity as following; horizontal coordination system, the relation of Polaris position and observation's position, declination and hour angle of star, diurnal motion of star, the motion of the sun and ecliptic, and the equatorial coordination system. The series of activities wanted students to describe the position of celestial sphere and diurnal motion by answering guided questions through hands-on activity. From our activities, students had to construct their mental model from three dimensional model of the celestial globe to draw two dimension picture of celestial sphere into paper. The model was implemented to thirty students in the 4th year science student teachers, Faculty of Education, Khon Kaen University. After the activities, the students' mental models were collected from five open ended questions about the star's position and the diurnal motion. The data was analysed by interpretive method. The interview was used to desclipe and got more information that disaper on the paper to explain and confirm what they thought. From the students' mental models found that all of students could understand and define the position of the NCP correctly. In the ecliptic topic twelve students could draw the ecliptic and describe about diurnal motion of the sun related to ecliptic and observer's latitude due to the rotation of the earth. There were fifteen students still did not show the ecliptic even they can show the position of the sun. The other students had no idea about the ecliptic. In addition, student still confused some concepts of the diurnal motion as following; 1) Even student can draw the ecliptic but they thought that the diurnal motion of the sun is on ecliptic path and 2) students thought that only observer at the equator can see the sun moving pass zenith.

Back to programme

(A269) EXPLORING 10TH GRADE STUDENTS' SCIENTIFIC CREATIVITY IN ECOSYSTEM LEARNING UNIT

Sittiched BUNPAPANPONG, *Kasetsart University*
Chittamas SUKSAWANG, *Kasetsart University*
Ekaphan KRAICHAK, *Kasetsart University*

Abstract
Science education in Thailand is in a crisis. The Programme for International Student Assessment (PISA) scores clearly indicated that Thai students scored below the average for sciences in international standard assessment. It implies that science educational system in Thailand does not reach the international standard of quality. One of the major reasons may have to do with the conventional current practices in science instruction, which forces students to memorize contents instead of enhancing student's divergent thinking and developing problem solving skills. From my experience as biology pre-service teacher in a high school. I have an opportunity to teach 10th grade students about the ecology. Meanwhile, I became acquainted with the problem of Thailand education in all levels, particularly at national level, Thailand overall PISA scores fallen far below average in comparison with other countries in the same region. To make matters worse, those scores have tended to decline significantly for the entire time. Trying to study biology, most students believe that learning through memorization without comprehension is a proper way, and consequently they cannot apply the content in a practical context. As biology student teacher, I recognise that creativity can help improve students' analytical skills and ability to apply knowledge outside the classroom, as well as encourage more class participation from the students. Therefore, my research project aims to observe and evaluate scientific creativity of 10th grade students in topic of ecosystem by developing a biology content-scientific creativity open-ended assessment and using it to evaluate students' creativity skill during the ecosystem unit. The assessment includes two main processes (thinking process and imagination process) and major composition of scientific creativity (fluency, flexibility and originality). The content of the ecosystem unit consists of seven subunits: aquatic biomes, terrestrial biome, energy transfer in ecosystem, interspecific relationship, biogeochemical cycles, biological succession and equilibrium of ecosystem. According to biology content-scientific creativity assessment, students earned the highest score in the fluency component in the topics of biogeochemical cycles and aquatic biomes equally, the highest flexibility in the topics of interspecific relationships, and the highest in originality in terrestrial biomes and biological succession. However, in the imagination aspect, the results differed from the thinking aspect. Student's fluency skill was the highest in the topics of terrestrial biome and energy transfer in ecosystem, the highest flexibility in ecological succession, and the highest originality in the topics of energy transfer in ecosystem, interspecific relationship and equilibrium of ecosystem. Even though this creativity assessment used the same unit, it could distinguish different learning outcomes in two different processes (thinking vs. imagination). With this finding, as a science teacher, researcher are hoping to create alternative solutions to develop scientific creativity through classroom management and teaching which allows students to practice more creative thinking for both divergent thinking from actual situations, and possibly unprecedented contexts which will improve students' long-term creative imagination thinking for example constructivism approach, 5E learning cycle, project-based learning.

Back to programme

(A270) PRE-SERVICE SCIENCE TEACHERS' VIEWS ABOUT THE NATURE OF STEM (NOSTEM): A COMPARATIVE STUDY BETWEEN THAILAND AND JAPAN

Chatree FAIKHAMTA, *Kasetart University*
Yoshisuke KUMANO, *Shizuoka University*

Abstract

Science, Technology, Engineering, Mathematics (STEM) education plays an important role in teaching and learning in the 21st century. Science teacher education is making a new effort to prepare STEM teachers and encourage them to transfer their STEM knowledge and practices to students in a particular classroom. In this research, we postulate that without understanding the nature of each STEM area and its integration, it may be difficult for teachers to transfer their understanding of the nature of STEM (NOSTEM) and provide students with opportunities to effectively engage in STEM activities. We will thus investigate pre-service teachers' understanding of both the individual discipline and integration among STEM areas. The challenge of this study is to develop the NOSTEM framework and investigate Japanese and Thai pre-service science teachers' understanding of NOSTEM. Japan is in East Asia while Thailand is in Southeast Asia, and the two countries have similarities and differences in terms of their cultures. In this study, NOSTEM can also be seen as the epistemology, sociology and values of STEM. The framework can guide specific questions as follows: What is each discipline (science, technology, engineering, and mathematics) and what is STEM integration? How does each discipline and its integration work? How do professionals in each discipline and its integration operate? How does society both direct and react to STEM endeavours? A NOSTEM questionnaire was developed and administered to 60 Thai and 50 Japanese pre-service science teachers. The questionnaire consists of a five-point rating scale (1-'absolutely not true', 2-'somewhat true', 3-'partly true', 4-'rather true', 5-'absolutely true'). The resultant data will be analysed in order to examine the reliability, validity and factor structure of the instrument in both countries. The internal consistency of each scale will be checked using the alpha reliability coefficient. The mean correlation of a scale with other scales will be used as a convenient index of the discriminant validity, while a series of factor analyses will be performed to examine the internal structure of each instrument. The ability to differentiate between the participants' understanding of NOSTEM in different years will be evaluated by conducting a one-way ANOVA for each scale with the year membership as the main effect. Lastly, the data will be also analysed to compare the means and the standard deviations of each scale of the questionnaire. A t test and a one-way ANOVA for each scale will be performed in order to examine which scales will be significantly different between countries, genders and year. The pre-service teachers' understanding of NOSTEM will be presented and discussed. Particularly, from a cultural perspective, the findings of this study will provide educational implications in terms of the commonalities and differences between the two countries with their own cultural features. The result of this study will be useful for developing STEM teacher education programs in that it can be used for setting goals, and designing instructional strategies.

Back to programme

(A271) ALTERNATIVE LENS FOR STUDENT'S RESPONSE ABOUT CHEMICAL BONDING

Patcharaporn ONTHONG, *Kasetsart University*
Akarat TANAK, *Kasetsart University*
Wanchai PLUEMPANUPAT, *Kasetsart University*

Abstract
Chemical bonding is a required concept for learning other advanced chemistry concepts such as organic chemistry and biochemistry. However, chemical bonding is well-recognised as one of difficult concepts in learning chemistry because of the abstraction. Previous study indicated that students struggled to deep understand the concept. Constructing knowledge in chemistry involve learners to describe natural phenomena in three levels; macroscopic, microscopic and symbolic. One of the essential characteristics of chemistry is the constant interplay between threes levels of thought. Accordingly, three levels are the core understanding of chemistry that require learners to make connection. However, abandon of studies frequently report students' chemical bonding conceptions by considering epistemological categories, with an intention to comparing students' understanding with consensus view of chemists. Unfortunately, this way of viewing students' knowledge in science not only limits our understanding about how student visualize the microscopic world of chemical bonding but also limits our knowledge from grouping that seem to be not detailed. Therefore, a new approach to view student's cognition in chemical bonding will be present in this research. This study aimed to elicit students' conception of chemical bonding especially ionic bond and covalent bond concepts. A questionnaire with five open-ended questions was used with 30 grade-10 students enrolled in science enrichment program in a public school, Bangkok, Thailand. The research tool was validated by three experts in teaching science. The student's responses were pulled out from sea of data by finding the resemble answers that hold assimilative views. After that, themes were created from cognitive keys of students' understanding. The analytical result revealed that the majority of Thai-grade-10 students hold a scientific concept in question about how to become a covalent bond (100%) but they hold a misconception about bond angle (23.3%). As a theme set, most of students used molecular structure (33.3%), followed by the reason explained by force (28.6%) as a main reason to express formation of covalent bonding and its shape. Meanwhile, from three main topics -covalent bonding, bond length and bond energy and molecular structure- the noticeable result showed that many students explain phenomena based on force and energy like interaction between atoms and electronegativity, respectively. Moreover, in the sophisticated content such as phenomena about dissolving in covalent compound, the responses were explained by more than two frameworks. Most students used type of element and molecular structure to interpret and elucidate this phenomenon. In the light of finding, result illustrated that Thai-grade-10 students generally visualised chemical bonding in the world of microscopic. However, students' response was still not deep in detail and could not link with a symbolic level. It can be challenging for chemistry teacher to find and create a practical instruction to encourage students' understanding and their ability to connect between the three levels.

Back to programme

(A272) TYPES OF PRACTICAL EXAMINATION IN CHEMISTRY LABORATORY AND THEIR EFFECTS ON STUDENTS' ACHIEVEMENT: BASIS FOR INSTRUCTIONAL GUIDELINES DEVELOPMENT

Maria Fatima GUMAPAC, *De La Salle Lipa, Inc.*

Abstract

Many research studies have been conducted to investigate the educational effectiveness of laboratory work in science education in facilitating the attainment of the cognitive, effective, and practical goals. These studies have been critically and extensively reviewed in the literature. From these reviews it is clear that in general, although the science laboratory has been given a distinctive role in science education, research has failed to show simple relationships between experiences in the laboratory and student learning. Moreover, a number of studies have been conducted to assess the different factors that affect the achievement and attitudes of students in their Chemistry laboratory classes. Both foreign and local studies focused on the effect of different strategies employed in the delivery of laboratory classes. Few experimental researches are done for the purpose of addressing the problems encountered in giving assessment in chemistry laboratory classes in particular. Furthermore, the effect of the type of test administered to evaluate the learning of the student in their laboratory classes is also not given much consideration. The most commonly used evaluation technique in the laboratory is move –system practical examination, wherein students are exposed to real specimens and are made to move from station to station under time pressure. Preparation and administration of this type of test have been a difficult task as claimed by the laboratory instructors. Another common type of examination given in Chemistry laboratory is the written test. This kind of assessment is criticised as not actual measure of laboratory skills that are expected to be honed in that particular class. Hence, alternative types of examination are being considered. It is a given fact that science cannot be meaningful to students without worthwhile practical experiences in the laboratory. According to Hofstein and Lunetta (2007), the laboratory has been given a central and distinctive role in science education, and science educators have suggested that there are rich benefits in learning from using laboratory activities. Some laboratory activities have been designed and conducted to engage students individually, while others have sought to engage students in small groups and in large-group settings. Teacher guidance and instructions have ranged from highly structured and teacher- centered to open inquiry. The issue is that although the science laboratory has been given a distinctive role in science education, research has failed to show simple relationships between experiences in the laboratory and student learning. Cognizant of the importance of bridging this gap, the researcher sought to determine if the type of practical examination has an effect on students' achievement in Chemistry Classes involving the Senior High School students in De La Salle Lipa. Therefore, this study is undertaken to establish a basis on how it can improve the quality of the delivery of instruction, not only for Chemistry, but for other courses with laboratory component as well.

Back to programme

(A274) MAIN FEATURES OF TEACHER PROFESSIONAL DEVELOPMENT PROGRAMS TO PROMOTE TEACHING PRACTICE: A LESSON LEARNED FROM PORTUGUESE AND THAI CONTEXT

Surayot SUPPRAKOB, *Phranakorn Rajabhat University*
Bernardino LOPES, *Universidade de Trás-os-Montes e Alto Douro*
Alexandre PINTO, *Polytechnic Institute of Porto*
Chatree FAIKHAMTA, *Kasetsart University*
Potjanart SUWANRUJI, *Kasetsart University*

Abstract
Numerous researches in professional development program (PDP) are aimed to enhance teachers' teaching practice, however, digging insight into PDP's characteristics especially in different contexts to promote successful change in teachers' teaching practices has been much greater challenge in science education. Our main idea of this study was sought to identify the characteristics and the lessons learned of what make two different PDPs in Thai and Portuguese contexts effective in changing teaching practice. The main research questions were a) What are the similarities of the characteristics of two PDPs? and b) What lessons did we learn from studying that make PDP effective to change teachers' teaching practice? The Thai's PDP aimed to develop teachers' pedagogical content knowledge (PCK) for teaching the nature of science whereas Portuguese's PDP aimed to enhance pre-service teacher teaching practice to promote scientific literacy. To answer those questions, secondary analysis was employed to study the different PDP which aimed to enhance teachers' teaching quality. The multiple data sources included a) the PDP course outline; b) video, field notes and transcriptions of PDPs, c) video, lesson plans, and field notes from observations of teachers' classroom; d) transcription of teachers' interviews of teaching practices and e) the transcription of the researchers' meeting. Constant comparative method was used to analysed. Throughout the datasets, we started with looking throughout the two of datasets about the key issues, evidences that become the categories. We then looked, and attempted to describe and assign the coding and categories. We finally engaged coding, categorizing, and generating the theme to answer those research questions. Next, the first author consulted to the second and third author about the trail of analysis till the data interpretation. The findings revealed that the two programs were entirely different in all structures such as aim, subject, level, timeline, structure of course, and participants, however, we found some similarities, for example, the two frameworks (PCK and formative situation) underpinning two PDPs overlapped in some elements. The ultimate goal of each program was also intended to enhance teacher teaching quality for promoting scientific literacy in student. In addition, the two PDPs had characteristics that make the two PDPs effective a) strong structure but give authority to teacher to adapt on their own, b) collaboration, cooperative work with team, c) learning science through real life context, d) practicing in action, e) reflection, f) ongoing support, g) sustaining strategies, and h) flexibility of PDP. We also found the similarity of theoretical framework underpinning each PDP that PCK and formative situation overlapped. Our findings shed light and contribute to the needs of effective PDP that emphasize on those characteristics to develop the productive PDP for success in changing science teachers' teaching practices. Implication for designing the effective PDP within teacher education are discussed.

Back to programme

(A275) DEVELOPMENT AND IMPLEMENTATION OF A CONCEPTUAL SURVEY IN RLC SERIES CIRCUITS

Pornrat WATTANAKASIWICH, *Chiang Mai University*
Kiadtisak SRISAIKHAM, *Chiang Mai University*

Abstract
Students often have specific difficulties understanding basic alternating current (AC) circuits, especially an RLC circuit. This circuit consists of a resistor (R), an inductor (L), and a capacitor (C) connected in series or in parallel. This circuit is a very important example of a resonant circuit, which has a minimum of impedance and the zero phase angle at the resonant frequency. This study had two goals—to construct a conceptual test on topics of series RLC circuits and to develop tutorial activities in teaching on this topics. For the first part of this study, 18 multiple-choice questions were constructed based on previous physics education research studies and previous exam questions. The survey validity was checked by three physics experts and then 5 questions were eliminated. The final version of RLC survey consisted of 13 multiple-choice questions and consisted of eight conceptual areas. Participants were 114 freshmen majoring in science and taking an introductory physics with calculus at Chiang Mai University on a 2nd semester of academic year of 2016. The RLC survey was administered online before and after an instruction on topics of RLC circuits. Students' responses after an instruction were used to perform item analysis and to determine statistical analyses. Average difficulty index (P = 0.56) and discrimination index (D = 0.43) indicated good quality. Kuder-Richardson reliability (KR-20 = 0.71) and Ferguson's delta (0.96) indicated that the test is reliable and has overall discrimination. For the second part of this study, tutorial activities were developed from previous studies. The tutorial activities included data from real series RLC circuits and were sequenced in order to help students develop basic concepts in drawing phasor diagrams, phase difference (lacking and leading phase), resonance and power in RLC circuits. An instructor used Predict, Observe and Explain (POE) to teach with these tutorial activities, and the instruction took 75 minutes. An effectiveness of the tutorial activities was determined in terms of average normalized gain <g> and effective size (d). Both measures (<g> = 0.51 and d = 1.75) indicated that the post-test scores were significantly higher than the pre-test scores. In other words, the tutorial activities were effective in improving student understanding. Further findings from student responses on both pre-test and post-test suggested that many students still had specific difficulties understanding RLC series circuit behavior that remain in spite of instruction. These difficulties included interpretation of phasor diagrams in terms of lacking phase and leading phase, as well as phase difference causing by frequency. The RLC survey may have potential as an instrument to probe student understanding on RLC series circuits, which is an important topic for both science and engineering students. Moreover, the findings were useful information for the instructor to improve her instruction.

Back to programme

(A276) TEACHING INTEGRATION OF 5E LEARNING CYCLE AND FLOWER COMPONENTS

Thasaneeya Ratanaroutai NOPPARATJAMJOMRAS, *Mahidol University*
Suchai NOPPARATJAMJOMRAS, *Mahidol University*

Abstract

This action research aimed to develop understanding of teaching biology based on 5E learning cycle using flower components lesson as a case study. One of learning outcome for both Master and Doctoral degree students in Science and Technology Education international program of University A was 'to develop innovations and learning processes in an ethical and appropriate manner compatible with the society and the educational needs'. They were not only required courses which tried to promote this main learning outcome of the programs, but selective courses also. Biology Education course is a selective course with 2 credits. All students who would like to carry on thesis with biology or related contents were recommended to register for this course. Two of the main learning outcomes of the course were 'to understand the different approaches in teaching and learning biology' and 'to develop an instruction including the integration between teaching and learning approaches with biology contents'. In the past, when students could not pass the first learning outcome, they would not pass the second learning outcome. The other problem was some students seemed to understand the first learning outcome, but could not integrate content with teaching and learning approach. 5E learning cycle or 5E instructional model was promoted in this study which regards to educational policy of Bhutan, Myanmar, and Thailand. Flower components topic was the basic topic which regards to Bhutan, Myanmar, and Thai curriculum. All participants studied this topic when they were students in basic education. Teaching materials were not too complicate to arrange. The hands-on activity could work in typical classroom. The data was collected in 2 batches of Biology Education course. The participants of the first batch were 4 Bhutanese students in Master degree level with 1 Thai doctoral degree student. The participants of the second batch were 4 Thai students and 1 Myanmar student in Master degree level with 1 Thai doctoral degree student. Reflection sheet and activity sheet of each student were analyzed using content analysis. The analysis of data indicated that implementations of the lesson plan based on 5E learning cycle using flower components as a case study were able to enhance students' understanding of the flower components content. Students were actively engaged along the learning. Results of the reflection sheet also showed students' appreciation about theory into practice in biology education. Most of them reflected that they had confidence to implement 5E learning cycle into classroom. Most of them had positive feedback on the lesson plan which was included using video, PowerPoint slides, hands-on laboratory, and discussion in pair and in the whole class. Most of them agreed that development of lesson plan which was integrated teaching and learning approach and biology content would be useful for them to implement in their countries in the future.

Back to programme

(A277) USING CLASSROOM ACTION RESEARCH TO PROMOTE PRESERVICE TEACHERS' PEDAGOGICAL CONTENT KNOWLEDGE FOR INQUIRY-BASED LEARNING IN SCIENCE METHODS COURSE

Siriphan SATTHAPHON, *Petchaburi Rajabhat University*
Pattamaporn PIMTHONG, *Kasetsart University*
Teerasak WEERAPASPONG, *Kasetsart University*

Abstract
Inquiry learning is one process that can develop students' understanding of scientific concepts and processes of acquiring knowledge. The aim of this action research was to enhance preservice science teachers' understanding of pedagogical content knowledge for inquiry-based learning (PCK for inquiry) in science methods courses. Our research objective was to promote preservice science teachers' understanding of PCK for inquiry in a science methods course. The participants in this research were thirty-seven undergraduate students in the Department of Science and Technology, Faculty of Science and Technology, in Rajhabhut University, in the West part of Thailand. This study employed classroom action research to collect qualitative data using the concept of interpreting information about linking the knowledge of students and teachers related to teaching science through inquiry, and about linking theory to practice. I developed and implemented 12 lesson plans about inquiry teaching, focusing on modelling them for our students in the second semester of the 2014 academic year. Moreover, students were required to practice in real situations with joint lesson planning between students and us. During the course, I taught them explicitly about planning and about student assessment and engagement. They designed their own teaching and engaged in case discussions in class. All activities were focused on practical skills and on self-reflection by our students. The multiple data sources consisted of the preservice science teachers' self-reflections, field experiences video reflections, lesson plans, teachers' log and a collection of related documents were analysed in this study. The inductive process was employed to analyze data. The finding revealed that it became clear that although pre-service science teachers learned about general teaching, they also held some common misunderstandings about instruction related to learning management, assessment of learning, curriculum and student learning. They especially lacked experience in science teaching practice in real situations. I also generated research findings regarding five aspects of PCK for inquiry. I also found the ways to promote preservice teachers' pedagogical content knowledge for inquiry-based learning include I was an instructor and apparent inquiry role model for this methods course, giving feedback enables students to reflect their pedagogical content knowledge for inquiry-based learning, video-reflection helps students understand their own practice, lesson planning between instructors and students helps preservice teachers confidence their practice and practice in real situation allows the preservice teachers to understand their teaching science through inquiry. From instruction I found that the preservice teachers cannot design learning activity that have the aspect of inquiry teaching, misconception about learner connects explanation to scientific knowledge and defining learning objectives is not clear. This research also suggests that if people are interested in doing further research should enhance the experience of learning to pre-service science teachers as taught in school two or three times during the course should be an opportunity for pre-service science teachers to reflect on their own

to take effect from the first to improve the next time as well as the follow-up lead to practical teaching classes in schools as pre-service science teachers internship.

(A278) DESIGNING PROFESSIONAL DEVELOPMENT FOR IN-SERVICE SCIENCE TEACHERS THROUGH ASSESSING CHEMISTRY CONTENT KNOWLEDGE

Yna Camille MONGCAL, *Philippine Science High School - Main Campus*
Armando GUIDOTE JR., *Ateneo de Manila University*
Queena LEE-CHUA, *Ateneo de Manila University*

Abstract
The content knowledge of teacher was recognized as important factor that influence effective teaching and student achievement. In any educational reform and curricular change, challenges are inevitable. Teachers need to learn new teaching approaches and strategies, deal with new learning materials, and update knowledge of the subject matter. The success of educational change depends on the capacity of teachers to practice and deliver the prescribed expectations of the new curriculum. The implementation of the K to 12 Science program includes teaching science in a spiral progression approach. Professional development that aims to enhance and improve competence of in-service science teachers is a main concern. With the efforts to understand the variables attributed to ineffective teaching, a number of research considered content knowledge as factor leading to competence of teachers. Assessing the content knowledge held by in-service science teachers can give insight on the specific content learning needs. It can also serve as guide in planning and designing professional development programs to enhance teacher competencies. This study aimed to examine the content learning needs of teachers for professional development using mix method approach. Data reported in this study came from 38 in-service science teachers from a teacher education institution enrolled in a science education graduate program. Quantitative findings were obtained using a chemistry content knowledge test. Focus group discussions were conducted to obtain qualitative information and to validate quantitative findings. The content knowledge test revealed the least mastered topics in chemistry which includes chemical reactions, gas laws, the mole concept, chemical bonding, and solutions. Qualitative results were classified into three key findings. These include difficulties in answering the content knowledge test, challenges encountered in teaching chemistry using the new K to 12 science curriculum, and interventions that teachers believe would be helpful in enhancing their content knowledge in chemistry. These findings imply that even teachers are academically able, they still need a continuous learning specifically on the subject matter they are teaching. Moreover, this study showed that specific content learning needs of teachers vary depending on educational and professional background such as teaching experience, field of specialization, and trainings attended. Professional development should be aligned with the needs of teachers to successfully achieve its goals and address needs for improvement. School administrators, educational researchers, educators, and professional development providers should realign their professional development programs to the demands of the new K to 12 Science curriculum. This study provided additional strategy to address the training needs of in-service science teachers specifically in the content. Most of the professional development programs focused on the pedagogy and less on the subject matter. Finally, implications of this study showed that appropriate and responsive professional development programs can help in-service science teachers in providing an enriched science learning experience for students to develop science literacy in both content and process skills.

Back to programme

(A281) ENHANCING ELEVENTH GRADERS MENTAL MODELS OF SOLIDS, LIQUIDS AND GASES THROUGH MODEL-BASED LEARNING WITH ARGUMENTATIONS

Warapa SUSINGRAT, *Kasetsart University*
Chatree FAIKAMTA, *Kasetsart University*
Surasinee KITYAKARN, *Kasetsart University*

Abstract

Recent research studies have been continuously reported that students have misinterpretation about significant ideas in a variety of science core concepts. Previous literature indicates that the mismatch between students' ideas and scientific consensus ideas may originate from students' mental models. Especially in chemistry lessons, if students can create their own mental models of some phenomena that they are interested, they can present it in the expressed models for explaining that events. Model-based learning with argumentations (MBLA) has been and approach that using in the classroom as expressed, estimate and adjust model device help students understand difficult chemistry concepts. Argumentation with co-construction using claim, evidence and rebuttals from original mental models is challenge help students develop their explanations at particle levels and relate to macroscopic events. This qualitative research is aimed at developing and investigating eleventh graders' mental models in the topic of solids, liquids and gases through model-based learning with argument. Data were collected from 29 students (11 boys and 18 girls). Pre-post open-ended test in the topic of Liquids, Solids and Gases (LSGT) consisting of 7 topics; states of matter, states of change, crystal and allotropy, diffusion, surface tension of water, Boyle's law and Charles's law, was used as a research tool. Data were analyzed though inductive process-interpreting and inferring data. According to Chi and Roscoe (2000), the mental model was categorized into 6 patterns. The findings indicated that prior to Model-based learning with argumentations, students tended to build non-scientific mental models which means that their ideas were not alighted with scientific concepts. The students' mental models were simple and realist in nature whereas their explanations at particle levels were inadequate to explain macroscopic events. The students failed to link macroscopic, submicroscopic and symbolic levels, particularly in the topic of surface tension of water. The findings showed that students held incomplete mental models (ICMM) and flawed mental models (FMM) respectively. However, after engaging MBLA, most of them held more completed understanding in informed concepts and more transitional mental models. The result marvelled that in post-test in the topic of surface tension and crystal and allotropy, the patterns of mental models were more complete mental model (CMM). Students could draw and explain the given natural phenomena by linking between explicit phenomenon explanations to implicit features. In the topic that crystal and allotropy, students expressed correct scientific mental models explaining properties of luster and conductivity linking between freely roaming electrons throughout the fused ring layers. This study raised some questions that should be addressed in the future research on the use of the MBLA, for example, can modified Model-based learning with argumentations approach produce conceptual change where alternative student conceptions are firmly entrenched? MBLA be incorporated into the pedagogy of most teacher?

Back to programme

(A282) NATURE OF SCIENCE IN RELATIVITY: ANALYSIS OF KOREAN TEXTBOOKS

Wonyong PARK, *Seoul National University*
Seungran YANG, *Seoul National University*
Jinwoong SONG, *Seoul National University*

Abstract

In line with the curriculum reforms worldwide, the newly enacted national science curriculum of Korea highlights the nature of science (NOS), by explicitly stating it as a key element of science instruction for students in all age levels. While a body of research has addressed the importance of NOS education in Korea, only few number of these studies have shown interest in the textbook representations of NOS. With such a background, this study attended particularly to the NOS representation in relativity theory chapters of Korean physics textbooks—which was introduced to the national curriculum very recently, and also have rich historical and philosophical context that has full potential for NOS instruction. From the textbook analysis, we sought to develop some general ideas about the factors that shape the NOS appearances in textbooks regarding individual science topics such as relativity. The research question that guided the study was: To what extent and in what manner is the NOS aspects regarding relativity represented in Korean physics textbooks? To answer this, the relativity chapters from seven Physics I (Grades 11 to 12) textbooks published and authorize for use in the 2009 and 2015 revisions of national science curriculum were analysed, based on the 11 categories of NOS aspects proposed by family resemblance approach (Erduran & Dagher, 2016). This framework views science as a cognitive-epistemic and social-institutional system, in which different sub-aspects of science dynamically and holistically interact within a certain context given. During the analysis, NOS representations in each sample textbook were identified by two researchers to evaluate what aspects of NOS are being represented and how. An explanation of the result was attempted by looking into the historical-philosophical, rhetorical, and systematic backgrounds that are associated with textbook chapters' representation of NOS regarding relativity. The sample textbooks as well as relevant materials (i.e. the teachers' guides to textbook, national science curricula, curriculum guides, and textbook authorization criteria, instructions for textbook authors, etc.) were used in this. Several interesting findings emerged from the preliminary analysis. First, while textbooks are addressing both cognitive-epistemic and social-institutional aspects of science, in many cases, various NOS aspects of the relativity theory are presented in rather discrete and non-holistic way. That is, how each aspect of NOS is tightly and dynamically interrelated to each other in the scientific enterprise is being largely undermined in textbooks. Second, it was found that textbooks are using either of the two distinct ways ("scientist-centered" and "science-centered") to write the relativity theory, and the scientist-centered narrative style—in which the content is written in the perspective of scientists at the time—seemed to allow more opportunities for NOS themes to appear than the other style. From the result, we make some general suggestions on how to understand the NOS representation as described in respective science topics. A complete set of findings and the implications for textbook research, practice and policy in general will be discussed in the presentation.

Back to programme

(A284) INTERACTIVE LECTURE DEMONSTRATION AND INQUIRY- BASED INSTRUCTION IN ADDRESSING STUDENTS' MISCONCEPTIONS IN ELECTRIC CIRCUITS

Mark Anthony CASIMIRO, *Marikina Science High School*
Ivan CULABA, *Ateneo De Manila University*

Abstract

Misconceptions are the wrong concepts understood by the students which may come up based on what they experience and observe around their environment. This seemed to hinder students' learning. Six different misconceptions were determined by the researcher from the previous researches. Teachers play a vital role in the classroom. The use of appropriate strategies can contribute a lot in the success of teaching and learning Physics. The current study aimed to compare two strategies- Interactive Lecture Demonstration (ILD) and Inquiry- Based Instruction (IBI) in addressing students' misconceptions in electric circuits. ILD and IBI are two strategies which are interactive learning activities and student- centered. In ILD, teacher demonstrates the activity while the students have their predictions while in IBI, students perform the experiments. The study used the mixed method in which quantitative and qualitative researches were combined. The main data of this study were the test scores of the students from the pre-test and post-test. Likewise, an interview with the teacher, observer and students was done before, during and after the execution of the activities. Determining and Interpreting Resistive Electric Circuits Test version 2 (DIRECT v.2) was the instrument used in the study. Two sections of Grade 9 students from Kalumpang National High School were the respondents of the study. The two strategies were executed to each section; one class was assigned the ILD group and the other class was the IBI group. The Physics teacher of the said school was the one who taught and executed the activities. The researcher taught the teacher the steps in doing the two strategies. The Department of Education level of proficiency in the Philippines was adopted in scoring and interpretation. The students' level of proficiency was used in assessing students' knowledge on electric circuits. The pre-test result of the two groups had a p- value of 0.493 which was greater than the level of significance 0.05 ($p > 0.05$) and it implied that the students' level of understanding in the topic was the same before the execution of the strategies. The post-test results showed that the p- value (0.228) obtained was greater than the level of significance which is 0.05 ($p > 0.05$). This implied that the students from the ILD and IBI groups had the same level of understanding after the execution of the two strategies. This could be inferred that either of the two strategies- Interactive Lecture Demonstration and Inquiry- Based Instruction could be used in addressing students' misconception in electric circuit as both had similar effect on the students' level of understanding in the topic. The result of this study may greatly help teachers, administration, school heads think of appropriate strategies that can address misconceptions depending on the availability of their materials of their school.

Back to programme

(A286) DEVELOPING COMPETENCIES AND DISPOSITIONS FOR THE 21ST CENTURY THROUGH AUTHENTIC PROJECT BASED LEARNING

Boon Hwee NG, *Temasek Junior College*

Abstract

The main purpose of the research study is to explore teachers and students' perspectives of 21st century competencies and dispositions and how it can be developed through a project-based learning curriculum. This study is part of Japan Innovative Schools Network (ISN) 2030 Project supported by OECD. Through the research study, we hope to find out "What are teachers' and students' perspectives of 21st century education, particularly in relation to the competencies and dispositions, at Temasek Junior College (TJC)? "How is project-based learning used as a pedagogical tool to facilitate 21st century competencies and dispositions in students at TJC?" and "How do TJC students develop 21st century competencies and dispositions through project-based learning curriculum?" Through TJC Science Department's in-house THINK© cycle pedagogy approach, students are provided with opportunities for self-directed and collaborative learning, while developing critical thinking and evaluation skills through analysis of real life problems. THINK© Cycle pedagogy is a holistic approach that incorporates inquiry-based learning, problem-based learning and project-based learning. It comprises 5 elements: Trigger, Harness, Investigate, Network, Know. The pedagogical approach provides students with experiential learning that expose them to the 3 domains of MOE 21CC Standards and Benchmark – Civic Literacy, Global Awareness and Cross-Cultural Skills (CGC); Critical and Inventive Thinking (CIT) and Communication, Collaboration and Information Skills (CCI). Each learning activity, work assignment and authentic transfer task (ATT) may incorporate either all 5 elements of THINK© Cycle or only selected appropriate elements of THINK© Cycle accordingly. This study was performed on 60 students in 2 classes of Integrated Programme Year 2 (equivalent to Secondary 2 students, or Grade 8), about 14 years of age, in TJC who are taking Green Science as lower secondary compulsory subject. The students were exposed to an environmental science group project (aka Authentic Transfer Task -ATT) over a period of 12 weeks with in-class discussions and outside-class discussions with their respective teachers. Each group investigated one of the three types of pollution (air, water, land) caused by man's activities and its effects on the environment by comparing Singapore with one other country as case study. From the students' product deliverables of (i) a scientific report; (ii) a presentation; and (iii) a digital information brochure, video or poster, we study the extent to which our students have developed 21CC and dispositions via project. The project assessment rubrics are aligned to MOE 21CC Standards and Benchmarks for Secondary 2 level in the 2 domains of CIT and CCI. Data sources included students' project deliverables and assessment performance. Teachers' perspectives elicited through interviews and reflections highlighted the gains and the challenges encountered against contextual realities. Students' perspectives elicited through Focus Group Discussion and self-reflection survey provided useful insights into the impact of the project on students' learning. Through the analysis of results, we could gain a deeper understanding of 21st century competencies and dispositions and the potential and limitations of project-based learning. Pedagogical implications and recommendations for future work will also be presented.

Back to programme

(A288) PRE-SERVICE TEACHERS' ENACTED TOPIC SPECIFIC PEDAGOGICAL CONTENT KNOWLEDGE IN RELATION TO LEARNER PERFORMANCE

Olutosin Solomon AKINYEMI, *University of the Witwatersrand*
Elizabeth MAVHUNGA, *University of the Witwatersrand*

Abstract

The uniqueness of teachers' Pedagogical content knowledge (PCK) lies in its power to improve instructional quality and consequently learners' performance. It is understood that the ultimate goal of science teacher knowledge research must not only be to understand teacher knowledge but also to improve teaching, thereby improving learners' performance. The current review of literature reveals that research investigating teachers' pedagogical content knowledge (PCK) has predominantly been at the level of description. This means that little is known about how teachers' PCK enacted in the classroom is closely linked to the learners' performance. This paper reports on the preliminary findings of the on-going PhD study that investigates the physical science pre-service teachers' Topic Specific PCK in organic chemistry in relation to learners' performance. The study employed a mixed method research design with a case study of five pre-service teachers as the research strategy. The pre-service teachers were in their third year studying for a Bachelor of Education degree at a University in South Africa. The study was located in a chemistry methodology course where there was a six weeks intervention that explicitly discussed the transformation of content knowledge (CK) of organic chemistry using the construct of TSPCK. The intervention was organised into a total of 12 sessions of 50 minutes each. The discussions were framed around the model of Topic Specific PCK (TSPCK) which consists of five knowledge components that enhance the transformation of content knowledge in a specific topic. The knowledge components include learner prior knowledge, curricular saliency, what is difficult to teach, representations and conceptual teaching strategies. Following the intervention, the pre-service teachers were followed into the classroom teaching of two concepts in organic chemistry to Grade 12 learners in two South African high schools. Each of the pre-service teachers taught a class of 15 learners who were in Grade 12. Data were drawn from two lessons which were taught by each pre-service teacher. The lessons were video-recorded. Data were also drawn from the pre and post achievement tests conducted with the learners before and immediately after the lessons. This study adapted learners' achievement test tools which have been used and validated in similar previous studies. In analysing the lessons delivered by the pre-service teachers, this study used a qualitative in-depth analysis method. The analysis examined the components of TSPCK enacted by the pre-service teachers and the nature of integration of the components as the concepts were being explained to the learners. Rasch Model Analysis method was used in analysing learners' responses to the achievement test tools. The preliminary analysis of data suggested that: the pre-service teachers seemed to have demonstrated a classroom teaching profile with more TSPCK episodes in the proficient category of the TSPCK rubric; and the learner performances seemed to increase in positive strength in the cases of pre-service teachers who demonstrated a high quantity of proficient TSPCK episodes. The implications of the study were discussed.

Back to programme

(A289) TWO-TIER TEST TO INVESTIGATE STUDENTS' DIFFICULTIES IN INDICATING A DIRECTION OF DC CURRENT BY AMMETER

Suchai NOPPARATJAMJOMRAS, *Mahidol University*
Thasaneeya Ratanaroutai NOPPARATJAMJOMRAS, *Mahidol University*

Abstract
DC simple circuit is one of the topics that students who study in Thai curriculum need to learn before they graduated from the middle school. Electrical current is one of the main fundamental quantities in the topic of a DC simple circuit. Students have to know 1) the meaning of current, 2) how to calculate the amount of current, and 3) the direction of current. In the class, teachers can either simply tell students or give them a chance to observe the direction of a DC current through hands-on activity or demonstration. An ammeter (from Ampere Meter), the calibrated galvanometer, has always been used as a teaching tool to indicate the direction and to measure the amount of current in a DC circuit. This types of ammeter is constructed with a small pivoting coil, attached to a thin pointer that traverses a calibrated scale, of wire in the field of a permanent magnet and a tiny torsion spring to pull the coil and pointer to the zero position (middle area of the scale). The pointer can move to the left or right side of the zero position to indicate the direction of current in the circuit. The direction of current, which is depended on the configuration of the circuit, is always named as negative or positive current. This research aims to investigate students' difficulties when using an ammeter to indicate a direction of current in a DC simple circuit. The test is consisted of 2 two-tier questions, which are developed as the instrument to collect the data from 71 Grade 9 students of a school in Bangkok. The first tier was used to check students' ability to identify the direction of current. The purpose of the second tier was to collect students' reason behind their responses to the first tier. This could help researchers investigate students' understanding about how current flow in the circuit and also their difficulties to use an ammeter to indicate the direction of current in a simple DC circuit. Results revealed that only 7 students of the participants could give the correct response to the first tier of both questions. Only 5 from 7 students could mention the relation between the direction of current and circuit configuration, correctly. Even most of participants have already known that current move from positive to negative polar of the battery. The researchers have a plan to develop the multiple choice question (MCQ) test by using data collected by this two-tier test with more students. The MCQ test will be useful for teachers to collect their students' difficulties in using an ammeter to indicate the direction of a DC current and also students' understanding about the direction of current in a DC circuit.

Back to programme

(A297) THE WASTE - INTERDISCIPLINARY CONTENT IN CHEMISTRY EDUCATION

Melánia FESZTEROVÁ, *Constantine the Philosopher University in Nitra*
Marta KUHNOVÁ, *University of Ss. Cyril and Methodius in Trnava*
Lýdia PORUBCOVÁ, *Constantine the Philosopher University in Nitra*

Abstract
Environmental issues related to pollution, the protection of natural resources; the deterioration of air quality; pollution; hygiene and chemical effects substances; waste, energy; are really serious nowadays problems. The education standard, meaning not only the defined content but also a summary of the performance requirements for pupils who are able to demonstrate after learning the subject. We could define the waste as the proper treatment and the disposal of waste in the subject of chemistry are devoted to attention, which focuses more on the cognitive and psychomotor component. This intention led us to prepare a project aimed at modernizing the teaching and interdisciplinary approach within the category of waste and waste management. In the paper we describe the results we achieved during the first year of the project. We focus on the chemistry that has a close relationship to the environment. The chemistry at the 2nd level of the elementary school and in the 1st - 4th year of the 8 - year grammar school. The content is based on situations (activities) that have a chemical nature, are close to the pupil. The waste is also a waste material as a chemical of a different composition. In the category of waste, proper treatment and disposal of waste, the learner can discover the properties of the substances, the nature of their behaviour in nature and their interaction with the components of the environment. The problem is related to the increase in the amount of waste and the possibility of sorting, storing, but above all removals. The reason is the fact that the state of the environment, the individual ecosystems is related to the quality of our health. It is important to use the knowledge gained in chemistry and to orient them to the chemical composition of waste, the proper handling and disposal of waste and waste management. We would like to contribute to the interdisciplinary linking of science subjects. In the school year 2016/2017, we conducted a survey of the separation of selected waste paper commodities at two elementary schools and a grammar school in the Nitra region (Slovakia). This survey was focused on the level of knowledge and on practical application or the waste content. It was attended by 182 respondents aged 11-18. The survey shows that our pupils need to expand and supplement the information and latest knowledge about the chemical composition of waste. The primary objective was to broaden and complement the knowledge of new ones that pupils will learn and be able to implement in their activities. The learning process have to be appropriate to the learner and to the situation with respect to the individuality of the pupil, its own pace and overall personal development. Its content should guide human behaviour, predict possible risks with regard to the state of the environment and, above all, the preservation of the quality of its life.

Back to programme

(A298) PRE-SERVICE SCIENCE TEACHERS' CONCEPTIONS OF TEACHING: REFLECTIONS ON THE FIELD EXPERIENCE

Sharon BRAMWELL-LALOR, *University of the West Indies*
Marcia RAINFORD, *University of the West Indies*
Miguel ISON, *University of the West Indies*

Abstract
Field-based experiences are indispensable components of teacher preparation programmes as school placements provide authentic learning experiences in which pre-service teachers can work alongside cooperating teachers who mentor them and help them to hone their craft. Teacher training institutions also rely on cooperating teachers to help with mentoring pre-service teachers by modelling good practice; providing information about the specific teaching context and offering guidance where necessary. The School of Education at the University of the West Indies, Mona has sought to strengthen its collaborations with schools to ensure positive learning experiences for pre-service teachers. This is especially important for beginning teachers who are preparing for teaching on their own who are trying to understand classroom climate and culture. This paper addresses the conceptions of teaching held by pre-service teachers in a University teacher-training programme gained from their twelve-week practicum experience conducted in the final year of their preparation programme. One area of specific focus of this paper is on the pre-service teachers observations of and work with their cooperating teachers. This is because the School of Education had sought to strengthen its collaborations with schools through special mentorship training sessions for cooperating teachers. The paper reflects a qualitative design using the data collection strategies of written reflections and focus group interviews. The six pre-service teachers' written reflections and focus group responses were analysed to identify themes related to their conceptions of the teaching experience. The pre-service teachers reported on observing cooperating teachers using a wide range of student-centred teaching strategies such as questioning, group work and role play, which they emulated. By observing cooperating teachers they learned how to set ground rules for lab sessions, how to ensure students are settled before moving on with the class, questioning techniques (use of wait-time and follow-up questions) and classroom management. They learnt that high school students like to learn from each other and to participate in class activities. The pre-service teachers also reported their preferences for planning aspects of the lesson such as the introductory activities. This they found to be 'easy' and 'interesting'. They also reported that time management during lesson-delivery was their greatest challenge as they struggled to accomplish all they had planned within the time required. In addition, varying levels of support from the cooperating teachers were reported by the pre-service teachers. The pre-service teachers' reflections also highlighted the difficulty of the teaching profession however they reported high levels of motivation to continue in teacher preparation and beyond. The findings will be significant in assisting in the planning and supervisory roles of teacher educators and cooperating teachers at all levels of the educational system. The participating schools will also benefit from the findings by being made aware of the kinds of support needed by pre-service teachers while engaged in their teaching practicum.

Back to programme

(A299) ELICITING STUDENT ENGAGEMENT IN SCIENCE IN INFORMAL SETTINGS

Miguel ISON, *University of the West Indies*
Sharon BRAMWELL-LALOR, *University of the West Indies*

Abstract
Science is often perceived by students to be conducted in laboratories by scientists bearing stereotypical features such as white lab coats, wearing glasses, having unkempt hair and often working alone. This is perpetuated by how science is taught in schools where practical work is usually associated with and conducted in laboratory settings. Students carry out ritualised procedures which do not connect to their real-life, everyday experiences. In addition, teachers are of the belief that science activities always need specialised, expensive equipment. Students also have various experiences with science such as reporting it as being boring, difficult or irrelevant. Research into the teaching and learning of science has shown that students learn best when they find the experience meaningful and they are actively engaged in the process. This is supported by learning theories such as constructivism and brain-based theories that promote the use of interesting, hands-on and authentic learning experiences. Hence, teachers need to understand that the laboratory is more than the procedures and the equipment and should be seen as one which facilitates learner-centred investigations of the natural world. At the secondary and tertiary level in Jamaica, students' performance in science over the last ten years has generally not increased and in some cases has declined and many students are not interested in pursuing science careers. This is of great concern especially in light of new curricula that have been prepared by the Ministry of Education is focusing on STEM and the 5-E teaching model. This paper reports on findings of a survey of individuals (mainly high school students) who participated in investigations grounded in science principles, while attending research day at a tertiary institution. Participants engaged in activities such as (i) making home-made batteries from regular, household materials and (ii) writing using "invisible" ink composed from household chemicals. The investigation was geared towards finding out how participation would impact knowledge, attitudes and perceptions of science. After participating in the investigations, over 60% of the participants' responses to the knowledge items on the survey were correct and over 80% indicated that their impressions of science had changed. Almost 100% of the participants indicated that they were likely to try the experiments at home. These results suggest that the use of real-life investigations had a positive impact on participants' knowledge and attitudes and their perceptions of science. The findings imply that science teachers should provide more opportunities for students' hands-on activities while learning science. Similarly, activities that relate to students' experiences are likely to assist in their retention of information and contribute to positive attitudes towards science. Students who are actively involved in novel, interesting, authentic science experiments are likely to develop a better understanding of science and scientists and in the future pursue science-related careers.

Back to programme

(A300) THE CHANGING CONCEPTION OF SCIENCE EDUCATION CURRICULA IN HISTORICAL US REFORM MOVEMENTS

J. Steve OLIVER, *University of Georgia*

Abstract

This presentation will use an historical lens to examine how science education has approached the curriculum of science education across a one hundred year period from mid-19th to mid-20th century. This examination will bring a historical perspective to the conference theme of Re-searching Science Education: Same Issues from Different Lenses. This perspective will be useful to conference attendees who wish to learn about past attempts to create or modify the curriculum in response to a reform goal. Science education emerged in the second half of the 19th century in the United States as various stakeholders including educators, philosophers and scientists pushed for formal education to move away from its total emphasis on classics and toward a curriculum that emphasized the subject-matter disciplines deemed valuable in the emerging society. The 1873 publication of The Culture Demanded by Modern Life: A series of addresses and arguments on The Claims of Scientific Education by E. L. Youmans was one of the first extensive statements on the importance of science curriculum within formal education. The scientific education called for by Youmans, and the other authors within this volume, was student-centered and founded in inquiry. For instance, in the introduction, Youmans wrote: "What, indeed, is the object of education…if not to arouse thought and provoke inquiry, as well as to direct them? (p. 36)." The Committee of Ten in 1892 laid out a plan for the inclusion of scientific disciplines and the nature of science in a standardization of the high school curriculum. Subsequent reform efforts were conducted across the 20th century. The most contemporary iteration of science curriculum can be found in the efforts to expand the traditional science coursework into integrated STEM education. The term STEM has, according to documents from the National Academy of Sciences, "developed wide currency in US education and policy circles." STEM education is, in fact, a world-wide phenomenon. In the Next Generation Science Standards (NGSS), the meaning of STEM is framed in terms of Core Disciplinary Ideas, Cross-cutting concepts, and Scientific/Engineering Practices. The idea of integrated curricula, both between science and other disciplines as well as within the scientific disciplines, has a very long history in science education dating at least as far back as the beginning of the 20th century. And yet this historical record is neither well known nor is it one of successful implementation. In many cases grand goals have served to stimulate grand projects which do not survive to fruition. It is important to re-examine these projects of the distant past as a means of creating understanding for current work and "re-searching" science education from a different lens. The presentation will examine historical documents referenced above and examine movements throughout the first half of the 20th century that called for the teaching of science to be reformed so as to be taught in a manner more in keeping with perceived needs of society. This topic is highly relevant to the conference theme.

Back to programme

(A301) EXPLORING A PROFESSIONAL DEVELOPMENT PROGRAM FOR ELEMENTARY SCIENCE TEACHERS: AN INTERNATIONAL PARTNERSHIP

Jeni DAVIS, *Salisbury University*
Katie LAUX, *University of South Florida*

Abstract

Professional development has been documented to increase teachers' science content knowledge and self-efficacy in teaching science (Haymore, Sandholtz, & Ringstaff, 2011), strengthen teachers' understanding of the nature of science (NOS) and inquiry practices (Buxner, 2014), and allow teachers to visualise science inquiry strategies and how to use them in their classrooms (Akerson, Hanson, & Cullen, 2007,). Explicit instruction in NOS can improve teachers' perspectives and change misconceptions of science inquiry in the elementary classroom (Akerson, et al., 2007). Authentic science experiences can improve teachers' ideas about NOS and science inquiry (Buxner, 2014). A U.S. university partnered with the National Secretariat of Science, Technology and Innovation (SENACYT) and educational leaders of Panama to develop a summer professional development (PD) program for elementary teachers in Panama. This PD was comprised of three month-long experiences in which Panamanian teachers learned about elementary science teaching methods, biology, ocean science, and physical science through online and face-to-face modules. The face-to-face components were delivered by U.S. university faculty in Panama for two-and-a-half days twice a month (during Week 0 and Week 4). The online modules occurred during Weeks 1-3. The purpose of this mixed-methods research study was to explore the effectiveness of this professional development program. Specifically, we sought to understand the impact of our PD model on Panamanian elementary school teachers' self-efficacy toward teaching elementary science, perceptions of nature of science and inquiry, and science content knowledge. Three questions guide our research: (1) How does this PD influence elementary teachers' beliefs toward science teaching and learning? (2) How does this PD influence elementary teachers' understandings about the nature of science (NOS) and inquiry? and (3) How does this PD influence elementary teachers' knowledge of science content? 44 of the 47 teachers agreed to participate in our study. Qualitative and quantitative data are being used to answer the research questions. Three surveys were administered at the beginning of the PD program in April 2017 and at the end of the program in September 2017. The STEBI-A survey, developed by Riggs and Enoch (1990), measured the elementary teachers' feelings of efficacy towards teaching science. The science inquiry survey from Buxner (2004) assessed the teachers' perceptions of NOS and inquiry. And a science content knowledge assessment was provided by SENACYT, using questions adapted from the ICFES, Colombia. We are also reviewing artifacts gathered from the teachers such as application essays, assignments submitted throughout the PD, and data from informal interviews. Qualitative data will be analysed through an inductive analysis utilizing principles of grounded theory (Glaser & Strauss, 1967; Charmaz, 2006; Strauss, & Corbin, 1990). We have access to demographic data of both teachers and their schools that may be used to describe our findings. Finally, instructor notes and reflections collected during the face-to-face component will be used to analyse evidence of teacher learning. While we are unable to report initial

findings in this abstract, we feel that our study will be of interest to the ISEC membership as we re-search PD in the context of an international partnership.

Back to programme

(A302) SCIENCE TEACHER PREPARATION VIA BLENDED AND FACE TO FACE PROGRAMMES: A COMPARISON OF TEACHERS' PROFESSIONAL LEARNING AND SENSE OF EFFICACY BEFORE AND AFTER THE PRACTICUM

Marcia RAINFORD, *University of the West Indies*

Abstract

For over sixty years, The University of the West Indies (UWI) has offered the Post Graduate Diploma in Education (PGDE) for certifying graduate teachers. Prompted by the UWI's strategic mandate to service the needs of its non-campus territories, the School of Education at Mona extended the PGDE to small island states and remote sections in larger islands across the Caribbean in 2014. The expansion was made possible by using blended delivery modes to supplement the face-to face modality. Blended learning involves the use of synchronous online sessions as well as face to face and online sessions. Teachers are trained in seven disciplines and since its inception, approximately forty two science teachers from five Caribbean territories have been trained via blended delivery. Along with knowledge of content, learners, curriculum and necessary pedagogical skills, teachers also need to feel confident in their ability to organize and carry out actions required to teach in given contexts. Delivering the PGDE to several Caribbean islands via blended modality presents new opportunities for comparing science education students' professional learning with that of students trained via the face to face programme. As students are drawn from different countries, we are also in a position to learn about how students from different contexts benefit from the science education programme. This study sought to find out how the PGDE participants from the blended and face to face programmes perceive their preparedness for teaching before and after the Practicum. Teacher self-efficacy is used as a measure of teachers' sense of confidence in their abilities, to effectively engage in teaching. A total of forty science education students participated in the study. Drawing on empirical data collected from PGDE students from Jamaica, Dominica, St. Lucia Montserrat and Bermuda, data gathered using the long form of the Tschennan-Moren and Woolfolk Teachers' Sense of Efficacy Scale (TSES) compares the teachers' sense of efficacy related to student engagement, instructional strategies and classroom management before the practicum period. A modified scale ranging from 1 -5 instead of the 1-9 scale in the original instrument was used. Science education students' portfolio reflections on the experiences during the practicum were used to ascertain aspects of teacher professional learning reported at the end of the practicum. Data for the two cohorts of science education students are being analysed. However, findings based on the analysis of the TSES data for one cohort of PGDE students drawn from all seven subject areas, showed that the mean scores for teacher efficacy was moderate for students for both face to face and blended programmes on all sub-scales. There was a significant difference between the means for students from the face to face and blended programmes on all sub-scales in favour of the students in the blended programme. The effect sizes (medium to high) suggest that there is practical significance in the mean differences. Implications for delivery of teacher certification programmes using blended modes of delivery in small island states will be discussed.

Back to programme

(A303) A PHENOMENOLOGICAL STUDY OF THE EXPERIENCES OF SUCCESSFUL WOMEN IN SCIENCE FIELDS

Jonathan HALL, *University of Central Florida*
Malcolm BUTLER, *University of Central Florida*

Abstract
Girls and women face several forms of gender-based biases and discrimination in the science community. This includes social norms that prevent equitable learning experiences for boys and girls and policies that hinder women's opportunities to advance in the workplace. These issues create difficult circumstances for girls and women to develop positive science identities. Since these difficult circumstances exist, science education and sociology researchers have commonly used a deficit model to learn about their experiences, achievement, and attitudes. However, there are girls who aspire to be scientists and women who have been and who are successful in science. The objective of this study will be to learn about the experiences of successful women who are professionals in science fields. This aim guides researchers to investigate an ongoing issue in science education from a different lens. The conceptual framework is based on a sociocultural perspective on identity and identity formation that incorporates figured worlds and identity work. Through this lens, identity is not a static characteristic, but fluid practices that are influenced by contextual factors. Figured worlds provides an analytical lens on how setting, culture, and historical factors affect the way people perceive and value themselves and others. Therefore, identity formation is based on accumulated experiences, feelings, and cognitive understandings that affect how people perceive themselves and their figured worlds. The study will be guided by two main research questions. The first main research question is, what are the experiences of successful women working in science fields? Sub-questions will investigate participants' experiences prior to college, during college, and as a professional. The second question is, if any, what are the differences in participants' experiences based on race and socioeconomic status? Descriptive phenomenological methods will be used to collect and analyze the data. Ten to 15 participants will be chosen based on their length of time in a science field and having equitable racial and socioeconomic representation among the sample. Participants will engage in three semi-structured interviews. The first interview will focus on the life history of each participant as it pertains to science. Then, the second interview will focus on the descriptive experiences of participants as professionals. Finally, the third interview will gain reflections of what participants communicated in previous interviews. Data analysis will be conducted to develop thick descriptions of participants' experiences. Findings could provide insight for educational researchers, curriculum developers, and science education methods instructors. First, research has been conducted to develop science identity models and findings from this study may further develop this aim. Second, planning and facilitation of co-curricular events that are specifically designed to promote inclusive environments for women in science could be guided by data generated from this study. Third, the stories of successful women in science could help structure lessons that cover inclusion and equity for preservice science teachers.

Back to programme

(A304) INTEREST IN STEM CAREERS: A COMPARISON BETWEEN PRIMARY AND SECONDARY SCHOOL STUDENTS

Norsharani ABDUL RAHMAN, *Universiti Kebangsaan Malaysia*
Illey Izyani IBRAHIM, *Universiti Kebangsaan Malaysia*
Lilia HALIM, *Universiti Kebangsaan Malaysia*

Abstract

Science, technology, engineering and mathematics (STEM) workforce is a key component in the creative and knowledge-based economy. However, the number of students interested in STEM subjects and STEM careers is declining. Various factors contribute to the phenomena among others learning science is difficult, science is boring and careers in STEM are seen to be limited. This study, based on the social cognitive career theory, investigates the factors contributing to interest in STEM career among primary and secondary school students. The two main factors; environmental factors (i.e. learning experiences, social and media) and internal factors (i.e. self-efficacy and perception of STEM careers) informed the study. This study also investigates the differences in interest in STEM careers based on gender and level of school. A questionnaire was administrated to 234 primary school students (aged 10, 11 and 12 years) and 101 lower secondary school students (aged 14 years). The data was analysed using descriptive and inferential statistic (two-way MANOVA). It was found that students (primary and secondary) have a relatively high level of interest in STEM careers. There was a significant difference between primary and secondary school students' interest in STEM careers. One significant finding is that the STEM self-efficacy in primary school students was greater than secondary school students. In addition, there was a significant difference in interest in STEM career based on gender. Male students showed a higher interest in engineering discipline compared to female students. All the investigated factors had significant correlation with interest in STEM careers however the strength of relationship between the factors differ between primary and secondary school students. Nevertheless, for both primary and secondary students, the main influence towards interest in STEM careers among primary schools children is their perception towards STEM careers. Two main implications arise from this study. First, the need to sustain STEM self-efficacy among the students throughout their schooling years as this belief's in oneself in STEM tasks shows the strongest relationship with interests in STEM careers. Thus, science teaching at the secondary where the level of students' STEM self-efficacy has declined can be addressed through science teaching and learning activities that are hands-on, project-based activities, and that deal with real world problems. Second, job prospects in STEM careers should be exposed to the students at an early age. One effective way is through involving students in STEM integrated outreach programs (e.g. that involves engineering design process) that not only provide students the opportunities to link relevant subject understandings to solve real world problems but are also able to learn the types of job scope in engineering fields. The findings contributed to the understanding about factors contributing to the level the interest in STEM careers between two levels of schooling, namely how initial interest in STEM careers was generated and thus is able to inform what types of intervention is needed to sustain students' interest in STEM subjects and eventually in STEM careers throughout their schooling years.

Back to programme

(A307) TRADITIONAL KNOWLEDGES OF LOCAL WISDOM OF KAMPUNG NAGA (CIAMIS, INDONESIA) ABOUT ENVIRONMENTAL CONSERVATION AND SANITATION

Hertien SURTIKANTI, *Universitas Pendidikan Indonesia*

Abstract

The human perspective on the environment is strongly influenced by values that are believed by them. Both formal and informal education may support the human personality through environmental education. The purpose of this research was to investigate the environmental knowledge of Kampung Naga (Tasikmalaya, Indonesia) local wisdom people in implementation their environmental conservation and sanitation. The method in this research was descriptive qualitative. Primary and secondary data were collected using instruments. Geographical data (location, local area, and boundary line); demography data (number of population, belief, occupation, and education background); and organization system were obtained from the village head and literature study. Meanwhile, tradition; environmental knowledge; and environmental awareness of local people were collected using questionnaires, interviews, observation notes, and documentation from respondents (15 children around 15 years old, 15 adults and elderly local people). Based on observation study field, (a) Kampung Naga village has natural environmental landscape. It has river, forest, rice field, public meeting area, mosque, small shops and residential area within 1.5 hectare. Study results showed that they are living in Islamic ritual, mutual cooperation, simple life, and keeping their old adat tradition. (b) Most of the respondents (80%) had low education in primary school. Environmental education knowledge was obtained from schools, parents, elderly people and environment. Children were taught by giving demonstration and practical exercise in the field about environmental conservation and sanitation. For example doing exercise in agriculture area or planting the tree in the forest. In fact, their environment awareness was shown by good attitude in keeping the environmental conservation and sanitation. It can be shown by the presence of sacral forest, clean environment and traditional waste management properties. They believe that the presence of sacral forest may support and protect people's lives. Because that forest may keep the water resources for people's lives. If they cut the tree in the sacral forest, they must replace the tree. Therefore they may keep and conserve their forest. They believe with their sanction (karma). If they do not keep their sacral forest, they will get disaster. (c) The forest provides many native plants for their needs including herbal medicines, foods and house buildings. They have skill in making kitchen equipment using dried bamboo leaves. (d) Various wastes and garbages were managed well. Because the local people get used to recycling plastics, paper and other wastes. They recycled waste into organic fertilizer and hand made products (households). (e) This Kampung Naga is visited by many people for tourism, so litter bags were located at every 20 meter along the road. Therefore, they may keep environmental sanitation in their village. In general conclusion, Kampung Naga people have their life principle that they are not living in the environment, but they are living with environment.

Back to programme

(A308) ENHANCING ADVANCED PLACEMENT PHYSICS TEACHERS' KNOWLEDGE BASE

Justina OGODO, *The Ohio State University*

Abstract

Students' knowledge and understanding of scientific concepts depend mostly on the teachers' knowledge base (Shulman, 1986). Acquiring the knowledge base is critical for teaching physics because of the nature of the subject. The current state of physics education indicate that fewer numbers of physics teachers in America's high schools possess adequate physics content knowledge to teach the subject; most are teaching physics outside the content they are certified to teach such as biology, chemistry and general science; hence, these teachers are failing to meet the physics content needs of their students. In the state where this study was conducted only about 9% of physics teachers had degrees in physics or physics education, compared to 37% nationally (NCES, 2014; Meltzer et al., 2012; White & Tesfaye, 2014). There is a critical need to improve and enhance the physics knowledge base of these teachers because of the increasing enrollment in high school physics. The need is even greater for the advanced placement (AP) physics teachers because of the rigor involved in the curriculum.

This exploratory case study examined the influence of participating in a physics-focused professional development in a southeastern state of the United States. Seven AP physics teachers (n = 7) were purposefully selected from a larger population of physics teachers (N = 69) who were part of a three-year intensive in-service physics content training. The participants that included four males and three females had teaching experiences ranging from 2 to 20 years. All had completed two years of training, representing over 260 hours at the time of data collection. Quantitative and qualitative pre- and post-data were collected from classrooms observations, teacher interviews, and surveys with instruments that have been validated in multiple empirical studies. Participants' pre- and post-intervention PCK levels were captured using a PCK Essential Component rubrics (Ogodo, 2017). The rubrics had three categories; content, pedagogy, and pedagogical content knowledge and each category had five components. The rubrics was an effective tool, used to capture and assess the participants' knowledge base.

Results from the analysis suggest that there was a large treatment effect difference between the pre and post-intervention data. There were observable pre- and post-training differences in the level of participants' content knowledge and pedagogical skills. The result also showed a relationship between teacher knowledge base and their instructional practice; enhanced PCK led to more student-centered and reformed-based instruction post-training. Sunal and Wright (2006) note that teachers who are inadequately prepared tend to use more teacher-centered approaches and are unable to effectively use reform-based teaching. This leads to unfavorable student experiences and loss of interest in learning science (Duncan, 2010; Park, Jang, Chen & Jung, 2010).

Although these results represent initial empirical evidence of the impact of targeted physics-focused intervention on the participants, they highlight the need for targeted and content-focused continuous in-

service professional development because "science education requires a substantive change in how science is taught; an equally substantive change in professional development practices" (NSES, 1996, p. 56).

Back to programme

(A311) INTRODUCTORY PHYSICS COURSES AT KSU AND STUDENTS' PERFORMANCE TIERS

Fahad AL-SHAYA, *King Saud University*
Maher AL-ARFAJ, *King Faisal University*
Saad AL-OMRAN, *King Saud University*
Abdu AL_MUFTI, *King Saud University*

Abstract

Introductory physics courses are required as part of the preparatory year in scientific, engineering, and health colleges. Thus, it is especially important to remember that for many students, such courses are considered as indicators of their abilities to pursue a field of study. Reviewing such introductory courses according to various indicators reveals a type of organizational dynamicity and sought of improvement. This study aimed to introduce and investigate King Saud University (KSU) students' performance in introductory physics courses during the period of the first semester of the academic year 1431/1432 (2010/2011) to the second semester of the academic year 1435/1436 (2014/2015). The study looked at significant differences in students' performance according to various factors, including: physics course, semester, and gender. In addition, it searched the prediction of students' GPAs based on midterm, final exam, accumulative scores, and variations according to courses. To suit these aims, the study recorded and analysed 26092 male/female students tracked and provided by the KSU registrar office. The quantitative approach was used to investigate multiple hypotheses driven from the study questions. Descriptive statistics; including frequencies, percentages, and measures of central tendency were manipulated with statistical analyses; including analysis of variance and step wise regression to guide inferences, and to lead further investigations. The study showed that the overall percentage of passing introductory physics courses was 70.5 %, and the health profession students were the best in passing these courses by a percentage of 81.22%, while science major students were the least in passing the courses with a percentage of overall success of 54%. Moreover, the results showed significant achievement differences by gender to the side of female students. Finally, the results showed that the midterm and final scores were significantly contributed in predicting GPAs, and the midterm scores were more contributing in the variation of GPAs than the final exam scores. The results were discussed according to previous studies implemented either at KSU or at other educational organisations. For example, students' performance in phys. 104 was comparatively better than performance in phys. 103. This could refer to the types of assessment executed in both courses. In phys. 104, students were exposing to assessments in both Arabic and English languages, while in phys. 103 students were taking assessments in only English language. This result supports Alshaya's study (2014), which stressed the importance of elevating students' English language proficiency to improve their understanding of physics problems. Moreover, the results could be tailored to Ha and Fag's findings (2016) that a course such as phys. 103, about mechanics, seems to be more difficult to comprehend comparing to a course such as phys. 104, about electricity and magnetism, which is not only demanding a deep abstract thinking, but also strong spatial abilities. Consequently, the findings of the study are expected to assist decision makers at the deanship of academic affairs, and the physics and astronomy department in the college of science at KSU to recognize strengths and weaknesses

of introductory physics curricula, and to take necessary steps for improvement.

Back to programme

(A317) EFFECTS OF CONCEPT MAPPING TECHNIQUE AND GENDER ON NIGERIAN JUNIOR SECONDARY SCHOOL STUDENTS' COGNITIVE DEVELOPMENT AND ACHIEVEMENT IN BASIC SCIENCE

Bernadette OZOJI, *University of Jos*

Abstract

The study investigated the effects of concept mapping technique on Nigerian junior secondary two students' cognitive development and achievement in Basic science. The randomized pre-test, post-test control group design was employed in the study. The study had five objectives. To achieve the objectives, three research questions were raised and two hypotheses formulated. The purposive sampling technique was used in selecting three out of 24 junior secondary schools that had comparable facilities in Jos, Plateau State, Nigeria. A sample of 622 junior secondary school three students was drawn from 26, 303 students with the proportionate stratified sampling technique. The sample consisted of an experimental group and a control group. The experimental group was taught the concepts of atomic structure, acids, bases and salts; energy conversion and transfer, and heredity with concept mapping technique while the control group was taught the same concepts with the conventional lecture teaching method. The teaching of the experimental group was done by a trained research assistant in concept mapping technique in each of the three schools used for the study. The same teachers also taught the control group in the stated schools to guard against treatment bias. Exposure of the experimental groups to the different conditions of teaching lasted for 12 weeks after pre-test administration. Data for the study were collected using a Science Reasoning Tasks II and Basic Science Concept Achievement Test with reliability indices of 0.72 and 0.80, respectively. Three research questions were answered using means and percentages while two hypotheses were tested using t-test and Chi square statistics at 0.05 level of significance. The findings of the study showed that concept mapping technique had significant effects on students' cognitive development ($t=30.23 \geq 1.96$) and achievement ($t=27.84 \geq t=1.96$) in Basic science. The findings further showed that there were no gender differences between the science reasoning tasks scores and basic science achievement scores of students taught with the concept mapping technique. The implication of the study among others is that science and technology teachers should use activity-based instructional strategies, such as, concept mapping technique to enhance the cognitive abilities of students for improved achievement in science and technology. Furthermore, the findings of the studies show that female students can enjoy science lessons and do well in them to the same extent as their male counterparts. The implication is that science classrooms should be made gender friendly with innovative strategies of teaching and learning to stimulate cognitive growth in students, kindle and sustain their interest in the study of science subjects for enhanced achievement outcomes. It was finally concluded that the concept mapping technique is effective in enhancing students' cognitive development and achievement in basic science. Concept mapping technique is also critical in promoting cognitive development and basic science achievement of males and females.

Back to programme

(A318) EFFECTS OF V-MAPPING STRATEGY ON NIGERIAN JUNIOR SECONDARY SCHOOL STUDENTS' TEST-ANXIETY AND ACHIEVEMENT IN BASIC SCIENCE AND TECHNOLOGY

Bernadette OZOJI, *University of Jos*

Abstract
The purpose of this study was to investigate the effects of V-mapping strategy on Nigerian junior secondary school two students' test-anxiety and achievement in Basic Science and technology in Kaduna, Nigeria. Two research questions were raised and three null hypotheses formulated to guide the study. Pre-test Post-test randomised group design was used in the study. Eighty (40 male and 40 female) junior secondary II students in two co-educational public schools were used as the study sample. The population for the study comprised 3980 junior secondary two students (males=2095, females=1885) in 13 public schools. A sample of 80 students (males=40 and females=40) was selected using the hat and draw simple random sampling technique. Twenty male and 20 female students were randomly assigned to both the experimental and control groups. The Instruments for data collection from the sample were Basic Science and technology Achievement Test and Basic Science and Technology Test-Anxiety Scale with reliability indices of .78 and .89, respectively using the alpha method. The experimental and control groups were exposed to pre-tests before they were taught selected basic science and technology concepts using V-mapping and the conventional lecture methods, respectively. The experimental group was taught the said concepts by one research assistant in each of the two schools used in the study trained in the use of vee mapping strategy. The control group was taught the same concepts by the same research assistants using the conventional lecture method. Post-tests were administered to the experimental and control groups after six weeks teaching exercise. The research questions were answered using frequency counts, mean and standard deviation while the hypotheses were tested with analysis of co variance, and Chi-Square statistics. Findings revealed that the experimental group exposed to V-mapping strategy achieved significantly higher than the control group not exposed to the strategy in the basic science and technology achievement test. Furthermore, it was revealed that students in the experimental group had low test-anxiety contrary to students in the control group who had high test-anxiety. It was concluded that V- mapping strategy had significant effects on students' test-anxiety and achievement in basic science and technology. The finding on higher achievement by the experimental group is consistent with the study carried out by Gaiya (2013) which showed that the mean achievement score of students exposed to V-mapping strategy improved. The results obtained in this study could be attributed to active participation by the learners in using the materials during the V-mapping activities to get the right answers to the focus questions. The implication of the findings among others is that science and technology teachers should meta cognitive strategies, such as V-mapping strategy in engaging students effectively in science and technology classrooms and laboratories for reduced test-anxiety and enhance their thinking skills and achievement. Students and teachers of science and technology among others stand to benefit from the findings of this study. Teachers will be better equipped with V-mapping strategy for effective teaching leading to students' improved learning outcomes in science and technology.

Back to programme

(A319) SCIENCE CURRICULUM REFORMS AND ITS EFFECTS ON CLASSROOM PRACTICES: A CASE OF SOME SELECTED BASIC SCHOOLS IN GHANA

Charles Deodat OTAMI, *University of Cape Coast*

Abstract

The basic school science curriculum in Ghana has gone through five reforms from the period 1987-2012 with another reform initiative currently ongoing. These changes are aimed at improving the quality of science education at the basic level in order to lay a solid foundation for further studies in science. However, the continuous reforms of the science curriculum, it is argued, has the tendency to present serious challenges in its implementation. This is because there is the tendency that the more things change the more they stay the same. As such, this study sought to examine the consequences of these numerous reforms focusing on teachers' classroom practices and perceptions. In all, 30 public basic schools in two educational districts in the Central Region of Ghana were selected using purposive and simple random sampling techniques. Twenty eight teachers whose science lessons were observed. Two hundred and thirty six students were also selected for this study. Twenty-eight teachers as well as Two hundred and thirty six students were selected for this study. Although data were collected using varied methods, in this paper I report on findings from data obtained through document analysis (focusing on content of textbooks used by students), semi-structured interviews (teachers' perceptions about the various reforms) and classroom observations (teaching practices of focal science teachers). Analyses of the data from the interviews, teaching plans, and personal observations revealed that most of the teachers and their students relied on commercial textbooks as teaching and learning materials instead of the government approved ones. An effect of this is the teaching of misconceptions contained in some of these unapproved textbooks. For example, a document analysis of one of such unapproved textbooks is the assertion that an egg is an example of a non-living thing. This is false because an egg is the largest cell we know of. Also, results from the semi-structured interviews indicated that teachers' interpretations and implementations of curricular were based on their own values and their instructional experiences. An unintended consequence of the numerous reforms, was the finding that some teachers were using the 2002 curriculum although the current one is dated 2012. This suggests that some teachers appeared unaware of the changes made to the science curriculum leading to teaching of topics which were no longer in the current curriculum. The findings indicate that the enactment of a centralised science curriculum in Ghana has produced some unpleasant repercussions. For instance, the teachers interpret and implement the curriculum is directly related to their own values and practices. This is contrary to the perception teachers implement school curriculum as directed. Thus, it is argued that without the right of localised management (involvement of teachers), curriculum reforms themselves are inadequate to ensure realisation of its desired effects. This paper, therefore, draws attention of stakeholders to the fact that the enactment of curriculum reforms goes beyond just simple implementation to more complex dynamics which may change the original reform intents. It is hoped that findings in this study will offer useful lessons, for countries engaged in numerous curriculum reforms, the repercussions of such policy instability on teachers' practices.

Back to programme

(A320) ENHANCING STUDENTS' SCIENCE PROCESS SKILLS AND METACOGNITIVE AWARENESS THROUGH GUIDED INQUIRY LABORATORY ACTIVITIES (GILA)

Jellina ROSGA, Cavite National High School

Abstract

Determining the effect of Guided Inquiry Laboratory Activities (GILA) in enhancing the science process skills and the metacognitive awareness of high school students in chemistry is the main goal of this study. The topics covered in the study include competencies under the specialized Science, Technology and Engineering curriculum such as solubility and the factors affecting solubility, thus, purposive sampling was used in identifying the respondents enrolled under the specialized program. One intact class composed of 36 students were the respondents of the study and the single group pretest – posttest pre-experimental design was utilized. A total of six instruments were used: four of which were developed by the researcher—(1) guided inquiry laboratory activities (GILA), (2) a teacher–made science process skills test (SPST), (3) scoring rubric for the guided inquiry laboratory report, and (4) observation checklist on the presence of science process skills amongst the students in performing different guided inquiry laboratory activities); and two adapted instruments with minor modifications—(5) metacognitive awareness inventory (MAI), and (6) perception survey questionnaires on the use of GILA. Data were analyzed using t–test, weighted mean and the Pearson correlation formulas.

After using GILA, result of the t-test at 0.05 level of significance revealed that there is a significant difference between the pretest and posttest scores in the science process skill test. The use of GILA in teaching chemistry laboratory tends to enhance the performance of the students in the SPST. There is a significant improvement in the manifested science process skills of the students particularly in quantifying, interpreting, predicting, observing, classifying, inferring, measuring, experimenting, and communicating. In terms of identifying variables before and after being exposed to guide inquiry laboratory activities, the students performed equally well. The students' metacognitive awareness significantly improved from low to very high metacognitive awareness. They became more strategic and performed better especially when it comes to planning and sequencing of their own activity procedure. Also, they became more aware of what they know and how they acquire this knowledge after they were exposed to GILA. The Pearson r-correlation between students' science process skill scores and metacognitive awareness scores revealed a significant positive correlation. They have learned to achieve meaningful learning through various activities since they became aware of their own learning and thinking process. The students' overall perception on the use of GILA revealed that GILA are more interesting and enjoyable than the traditional method. It developed the students' science process skills as they perform each laboratory activity. The results of the study have wide implications for the improvement of students' performance in chemistry. Exposing them to GILA gives them the opportunity to develop their ability to work independently not just following the usual laboratory activities. Likewise, these activities provide teachers new methods of teaching the chemistry laboratory to avoid spoon feeding of information.

Back to programme

(A325) DO ENJOYMENT AND SELF-EFFICACY IN SCIENCE AFFECT ACADEMIC ACHIEVEMENT?

Martina DICKSON, *Emirates College for Advanced Education*
Shaljan AREEPATTAMANNIL, *Emirates College for Advanced Education*

Abstract
In the UAE, much emphasis has been placed upon STEM skills and knowledge in curriculum and teaching by national educational authorities. One of the ambitious goals of the educational reforms which have taken place in the country over recent decades include the improvement of students' achievement in national and international standardized testing, with a long term goal of increasing the country's Knowledge Economy Index. Some previous research in other countries has positively correlated high self-efficacy and enjoyment in science with achievement, which in turn should have an impact on the way in which science is taught and learned at schools. Therefore, there is a pressing need for educators, policy makers and other stakeholders to have access to data which can clearly present the interaction between these parameters. This study aimed to explore whether science achievement differed between females and males, but also whether their self-efficacy and enjoyment of science influenced this achievement. We draw upon students' responses to science self-efficacy and enjoyment questions included within the 2015 PISA study. The student achievement segment of the PISA assesses the extent to which students have acquired what are considered to be the "knowledge and skills that are essential for full participation in modern societies" (OECD, 2014). A total of 14167 students (7115 females, 7052 males) took part in the PISA 2015 assessments. Of these, 4329 students were enrolled in public schools (2501 females, 1828 males). We analysed this public school data using independent samples t-tests and structural equation modelling and found that female students scored statistically significantly higher in science achievement than males. Comparison of levels of enjoyment between female and male students showed that female exhibited statistically significantly higher levels of enjoyment in science learning than males. Both female and male students who reported higher levels of enjoyment scored statistically significantly higher on the PISA 2015 science assessment, but this association was stronger for females than males. Female students reported higher levels of self-efficacy than males, but this was not significantly related to academic achievement for either gender. The study is significant and novel due to its concrete finding of the importance of students enjoying the science they learn, since it is seen to affect achievement. This shifts the mindset of enjoyment in science learning as simply being intuitively pleasant, but also that it is critical in order to increase the numbers of students graduating with the skills and knowledge necessary to take up science subjects at tertiary level. This is particularly true in developing countries such as the UAE who place great emphasis on future knowledge economies. An implication of this study is that great emphasis needs to be placed upon pedagogy which students find engaging and enjoyable, both during in-service and pre-service teacher training.

Back to programme

(A326) PARTICIPATION, POSITIONING, AND POWER: OPPORTUNITIES TO LEARN IN A UNIVERSITY KINESIOLOGY CLASSROOM

Allison RITCHIE, *University of Toronto*

Abstract

Past studies in the science research have documented that people of colour and women continue to be underrepresented in science-related university programmes and careers. The need for providing equitable opportunities to learn (hereafter OTL) science in diverse, content-focused classrooms has been recognized as an important aim in educational research. Partially because of OTL has traditionally been conceived of quantifiable resources (e.g., qualified teachers, textbooks, equipment) and the subsequent assumption that equal access to OTL will lead to comparable academic outcomes, there has been limited research examining students' uptake processes of OTL. To better understand issues of equity, this critical microethnographic study explores how students' participation and acts of positioning shape their access to particular OTL within scientific discussions, set in a diverse, Canadian university, Kinesiology classroom. The research draws data from videotaped observations of classroom lessons, student interviews, and four vignettes of group work wherein two participants were the focus of the analysis. The video analysis focuses on how students go about learning together in scientific discussions by looking at the ways in which participation and acts of positioning unfold in intergroup interactions. Using a stimulated recall interview technique, the study also explores how the focal students identify and interpret their experiences within these interactions. Drawing on cultural historical activity theory, I describe the dimensions of the Kinesiology classroom activity system, which foregrounded ethico-moral considerations of scientific activity. Then two case studies of the focal participants are examined. The findings describe their verbal and non-verbal acts of positioning, highlighting how students' access to particular OTL may be facilitated and/or constrained by these positions, and acknowledge the different observations and interpretations between the researcher and focal students. One student appeared to take up the position of a facilitator, but in another setting, there appeared to be no expert or facilitator. Another focal student adopted a leadership role in one context, but in another activity, shifted from an initially more passive to a facilitator position. Using positioning analysis, these case studies allow the reader to see how certain aspects of identity become more salient in particular interactions as well as how these focal students' uptake processes influenced the distribution of OTL within groups. This critical microethnographic study's theoretical contributions include a synthesis of sociocultural theories of learning that affords a multilevel inquiry. The different grains of analysis offer a wider look at how science learning happens locally, and are simultaneously influenced by the structural organisations of learning and forces originating in other settings. Implications for science education research are also raised, including suggestions for a greater analytic focus on student-led spaces, and making visible the meso- and macro-level processes connected with local classroom events for a more coherent analysis of science learning in these environments. My analysis makes progress in understanding how these forces interact to shape the distribution of OTL within scientific activities, and the finer grain analysis helps us to further understand how these learning spaces are negotiated,

and how students enact, maintain, and resist social dynamics in various ways.

(A329) A MULTI-CASE STUDY ON TEACHING PRACTICES AND HOW TEACHERS USE TECHNOLOGY TO SUPPORT SCIENTIFIC INQUIRY IN 1:1 CLASSROOMS

Nel VENZON, *University of Southern California*

Abstract

Despite the widespread availability and frequency of use of technological tools in the classrooms, there is little empirical research on examining the teaching practices and how teachers use technology to support scientific inquiry. This multi-case study examined the teaching practices of two science teachers and how they used the technology to support scientific inquiry in 1:1 classrooms. Although previous studies recognized the importance of teachers' roles in inquiry classes, few have examined the teachers' role in implementing and supporting technology-enhanced tools in the classroom. Previous research provides little information with regard to teacher facilitation of learner-centered inquiry in classrooms equipped with technology. This study sought to help close the gap in research on teaching practices and how teachers use technology to support scientific inquiry. A qualitative study employing a multi-case study methodology was conducted with data collected from observations, interviews, and document collection. This study utilized the multiple case study method of examining two science teachers' classes (one ninth grade science class and one eighth grade science class) in two separate sites on the Island of Oahu, Hawaii. The teachers served as the unit of analysis for each of the two case studies. The findings of this study indicated that the teacher participants' use of time and technology supported simple inquiry. Technological tools engaged students in scientific processes, but not complex thinking or student questioning, during inquiry process. Furthermore, the study found that technology use supported student engagement in simple inquiry, with or without contextualized learning. Technology use supported cooperation and engagement of students in simple inquiry, with or without the development of scientific knowledge. Both teacher participants supported simple inquiry, not authentic scientific inquiry, when they used technology in their science classes over the course of the investigation. An implication for practice relates to having the knowledge of the type of inquiry that teachers should have when teaching science. Although both teacher participants and their corresponding students had in their possession and used some form of technology over the course of the classroom investigations, they demonstrated technology affordances that supported simple inquiry, not authentic scientific inquiry. One implication involves having the knowledge of the technology affordances that support authentic scientific inquiry. The use or enactment of reform-based scientific practices was not observed frequently over the course of the classroom observations. An implication for practice relates to student scientific practices when using technology to support authentic scientific inquiry. Another implication relates to the role of school principals in teachers' engagement in professional development programs. Although both science classes belonged in schools with a 1:1 technology initiative, the affordances provided by the technologies they "used" demonstrated features of simple inquiry, not authentic scientific inquiry. One implication for policy is that the role of implementing 1:1 technology initiatives in science classrooms, for the purpose of supporting student inquiry in science, is not fully understood. This study contributes critical knowledge on the teaching practices and how teachers use technology to support scientific inquiry in a 1:1 classroom setting.

Back to programme

(A331) COMMUNITY-BASED LEARNING IN ENVIRONMENTAL EDUCATION: ASSESSING STUDENTS' REFLECTIONS ON COMMUNITY ENGAGEMENT AND ENVIRONMENTAL KNOWLEDGE

Carmina DALIDA, *University of Santo Tomas*
Catherine Genevieve LAGUNZAD, *Ateneo De Manila University*

Abstract

Honing a new generation of learners to become critical-thinkers, and developing technical knowledge in assessing environmental phenomena are part of the goals of environmental education. One of the responsibilities of educational institutions is to provide meaningful learning experiences among students, which are applicable in all aspects of campus life and the learning environment. Relevant learning could have an impact on the development of their critical environmental awareness, concern and action, thus, providing a quality education that is caring of the Earth. Therefore, the education systems must aid in developing a sense of environmental stewardship as a lifelong learning. One of the pedagogical approaches by which the students can be connected to the real world is through community-based learning (CBL). Community-based learning is based on the premise that students learn to connect environmental concepts with the real world, hence, creating meaningful learning experiences. It provides learning experiences that are relatable to the students' lives and their communities, hence extending the learning beyond the walls of their classroom and realizing the relevance and applications of the subject matter. This study aims to evaluate the impact of community-based approach on students' reflections on community engagement, and on their environmental knowledge. The mixed method approach was used in this study, which involved the analysis of both qualitative and quantitative data. The qualitative approach was done through the analysis of students' written responses to open-ended questions, while the quantitative approach was done through nonrandomized control group pretest–posttest design. Two groups of students have participated in this study: (I) the traditional learning group and; (II) the community-based learning group. The thematic analysis of written responses revealed that both groups showed similarities on their insights about the environment. Also, the responses reflect values of conservation and protection. The community-based approach helped the students to recognize that their community serves as one of the resources of learning. It was further emphasized that the role of the members of the community is an important aspect of community-based learning, since they can help the students to recognize and develop deeper understanding of realities happening in their surroundings. The utilization of community-based approach had also shown positive effects on students' environmental knowledge. The independent samples t-test analysis revealed a statistically significant difference in the higher order thinking skills of the community-based learning group between pre-test and post-test scores. Moreover, the gain score analysis between the two groups showed that the community-based learning group had statistically significant higher level of environmental knowledge in comparison to the traditional learning group. Based on the aforementioned findings, it can be deduced that community-based learning is a promising approach in learning environmental issues. It also provides an opportunity to develop positive environmental attitudes through community engagement.

Back to programme

(A334) EMBEDDING MULTIPLE MODES OF REPRESENTATIONS IN OPEN ENDED TEST ON TRANSITION ELEMENT

Mageswary KARPUDEWAN, *Universiti Sains Malaysia*
Nilavathi BALASUNDRAM, *Universiti Sains Malaysia*

Abstract

Past studies suggested writing incorporated with multiple modes of representations (MMR) able to reduce misconceptions (Hand, Prain & Yore, 2001). Some studies also indicated that effective teaching method can promote the use of MMR in presenting the answers in open-ended test (Prain & Hand, 2004). Specifically, teaching using technological tools is identified as an effective method in encouraging students to use MMR. As such in this study, writing-to-learn activity (WTL) integrated with graphic organizer using 'popplet' application was used to teach the lessons on transition element. Following the teaching, MMR embeddedness in the open-ended test was measured. A total of 81 Form Six science stream students (19 years old) participated in this study which took place for 8 continuous weeks. Embedding MMR in open-ended test was measured at three levels: before, during and after the intervention. Mixed method design involving quantitative and qualitative measures were used to identify the ability of the students in embedding MMR in their open-ended test. Repeated measure one-way MANOVA was used to compare the means obtained from the three levels of open-ended test; pre-test, post-test I and post-test II. MMR embeddedness in open-ended test is analysed using rubric adapted from a study by McDermott (2010). Embedding MMR in open-ended test is evaluated based on three subsections which are text assessment, general alternative modes analysis and individual alternative modes analysis. Additionally, qualitative method is used to analyse the test responses from the students to describe the MMRs embedded. The result indicates that embedding MMR in open-ended test improved significantly from the pre-test to post-test I and to post-test II, Wilk's Lambda = 0.031, $F(2, 79) = 1241.618$, $\eta 2 = 0.969$; the effect of embedding MMR in open-ended test subscales are significant, Wilk's Lambda = 0.134, $F(2, 79) = 254.398$, $\eta 2 = 0.866$; the interaction between embedding MMR in open-ended test subscales and test time is significant, Wilk's Lambda = 0.111, $F(4, 77) = 154.416$, $\eta 2 = 0.889$. This shows there is an increase in embedding multiple modes of representation from pre-test to post-test II. Qualitative analysis showed that there is improvement in the embedding MMRs in open-ended test from pre-test to post-test II. Qualitative and quantitative result proves the intervention, WTL activity integrated with graphic organizer using 'popplet' application has improved the usage of MMR in open-ended test. Students with representational competence frequently employ MMR to explain phenomena, support claims, solve problems or make predictions from their findings and argue for their conclusion. This helps students to understand the concepts in transition element. Besides that, teachers can use the intervention in the chemistry classroom to encourage students to use MMR. This will help students to clearly express their view preciously in the context of chemistry because chemical knowledge is learned at three levels which are "sub-microscopic," "macroscopic" and "symbolic" level. This proves that MMR play important role in teaching and learning process.

Back to programme

(A337) FLIPPED CLASSROOM IN TEACHING BIOLOGY: ITS IMPLICATIONS ON STUDENT-CENTERED INSTRUCTION AND STUDENTS' ACADEMIC PERFORMANCE

Gladys Ann MALTO, *The National Teachers College*
Catherine Genevieve LAGUNZAD, *Ateneo De Manila University*

Abstract
In facing the 21st century learning environment, characterized by rapidly growing global knowledge and a continually advancing information and communication technology, educators must develop and adopt more appropriate teaching methods to meet the needs of a new breed of learners. Teachers must take on the challenge to commit to a paradigm shift from a teacher-centered to a student-centered learning style, focusing not on how to teach, but how to facilitate learning. Teachers must exploit the fact that the new generation students are born with technology, by adopting contemporary teaching strategies appropriate for students' learning styles. Moreover, teachers are encouraged to face the challenges of developing a variety of suitable instructional materials and activities to address the need of all students regardless of learning abilities, preferences and interests. A new method of blended learning that can be implemented to explore the potential value of online learning resources and technology is the Flipped Classroom. Flipped Classroom is a specific model of blended learning that involves online delivery of content and instruction, which maintains the connection between the classroom and the student. This model has been adopted widely at higher educational levels, but to a limited extent in basic education due to lack of facilities and infrastructure, and scientific studies to observe. This study focuses on the effects of flipped classroom approach on students' academic achievement in high school Biology under the K-12 program. The quasi-experimental design was used in this study, wherein two randomly assigned groups participated: (I) the Traditional Group (TG) and; (II) the Flipped Classroom Group (FCG). The Traditional Group was taught through conventional way, while the Flipped Classroom Group was exposed to both online and face-to-face instruction. The study also aims to collect data from teacher observations that can provide multi-perspective assessment of the implementation of the flipped classroom approach. The implementation of the flipped classroom approach was evaluated by teacher-observers based on the following aspects: (1) the teacher's role; (2) how students learn and; (3) student – teacher interactions. The results of the quantitative analysis of the two groups' gain scores revealed that the FCG had significantly higher gain scores than TG. This is a manifestation of improvement of the students' understanding in Biology. In addition, the multi-perspective assessment by the teacher-observers reflect that the flipped classroom offers student-centered instruction. Based on the teacher-observers' perceptions, the approach succeeded in shifting the focus of learning from the teacher to the students, who take responsibility for their own learning. This shows that the teacher merely serves as a facilitator of learning. The teacher-observers also see evidence of high levels of engagement, participation and collaboration during class activities. In this way, students take part in the dynamism of the teaching-learning process, through creating, assessing and reflecting on their own learning.

Back to programme

(A339) CONSIDERATION OF THE DISCIPLINARY NATURE OF STEM EDUCATION: A REQUIRED PEDAGOGICAL APPROACH

Gillian KIDMAN, *Monash University*
Niranjan CASINADER, *Monash University*

Abstract
The proposed paper is primarily theoretical, however illustrative classroom examples are provided. The premise is that an alternative theoretical approach to the consideration of Science, Technology, Engineering, and Mathematics (STEM) education is necessary. For STEM to be effective in student learning, consideration must be given to its cross-disciplinary nature. This must occur not only within (internal to), but also across (external to) disciplines in an integrated manner. In other words, today's teachers not only need to know what counts as knowledge of a particular discipline, and how to demonstrate understanding within disparate disciplines, but also about how to integrate and synthesize knowledge in a trans-disciplinary fashion between several disciplines at once; for example, how to integrate and synthesise knowledge in STEM. This paper, examines disciplinary integration, both theoretically and then in school practice. The forms of disciplinary integration relevant to STEM education are: cross-disciplinary (viewing one discipline from the perspective of another); multi-disciplinary (practitioners from different disciplines working together, each drawing on their disciplinary knowledge); inter-disciplinary (integrating knowledge and methods from different disciplines, using a synthesis of approaches); and trans-disciplinary (moving across disciplines from a perspective of disciplinary expertise). A teacher's ability to undertake disciplinary integration in their classroom is the professional attribute of inquiry literacy (Kidman & Casinader, 2017). The acquisition of inquiry literacy is increasingly important in an era when teachers, students and professionals are often expected to demonstrate understanding, not only in a single school subject or discipline, but also to transfer their skills and knowledge to other or unfamiliar school subjects or disciplines in the conduct of their professional duties – the highly considered 21st Century Skills. Fostering cross-disciplinary conceptions of inquiry-based practices lessens the struggles that teachers experience when undertaking inquiry-based practices in individual disciplinary fields. Many teachers do not understand the differences between the different forms of integration, and this misunderstanding has led to a conflation in their usage. This phenomenon is preventing, for example, the successful integrated teaching of STEM where cross-disciplinary and multi-disciplinary approaches are used interchangeably instead of the required inter-disciplinary approach. This misunderstanding becomes more apparent where inquiry-based practices are proposed in STEM education, further supporting the need for an understanding of trans-disciplinary teaching. The educational research literature has many examples of explorations into the potential of inter-disciplinary teaching (for example, Levin & Nevo, 2009; Nikitina, 2006) and inquiry-based practices (both teaching and learning) (for example Kidman & Casinader, 2017; Mintrop, 2004; Rico & Shulman, 2004; Shulman & Sherin, 2004). However, few have examined the inter-disciplinary inquiry-based practices. This paper considers the use of inquiry-based practices and inter-disciplinary teaching in a STEM context to show that with a stronger understanding of how to integrate and synthesise knowledge, enhanced cross-discipline learning is more likely.

Back to programme

(A340) RELOOKING ENVIRONMENTAL SCIENCE EDUCATION: THE PEDAGOGICAL VALUE OF COMMUNITY-BASED RESEARCH PROJECTS IN HIGHER EDUCATION

Tai Chong TOH, *National University of Singapore*
Siok Kuan TAMBYAH, *National University of Singapore*

Abstract
Project-based learning is widely used to enhance students' metacognitive abilities in post-secondary education. However, most studies to date have focused on the implementation of courses, and empirical research on this pedagogical method is lacking. We present a community-based research (CBR) model that creates a unique learning environment in higher education through the formation of a tripartite partnership among students, educators and the community to collaboratively engage in research to effect social change. In this case study, a team of undergraduates (n = 3) and educators from the university collaborated with a local high school through the capstone experience module offered by a residential college at the university. This undergraduate module provides an interdisciplinary learning experience that facilitates the application of academic disciplines to community issues and aligns to the community-based research model's objectives of informing the community about policy implications and filling in knowledge gaps. After an initial needs assessment conducted with the educators at the high school, the undergraduate team developed and implemented an eight week environmental science education programme that focused on improving the secondary school students' knowledge, attitudes and habits towards food waste reduction. This project presented two key benefits. First, the pre- and post- project quantitative surveys administered to the students revealed significant improvement in the students' attitudes in the group that attended the programme (n = 10, 11% increase) compared to the control group (n = 19, 0.3% increase). The effects on the students' knowledge and habits were marginally positive and we inferred that these attributes required sustained long term interventions to effect changes. Second, the project presented pedagogical value for higher education. Qualitatively, several key themes emerged from the undergraduates' personal reflections: they highlighted that the project was pivotal in helping them appreciate environmental stewardship, teamwork, ethical reasoning, adaptive decision-making, interdisciplinary learning and problem solving. In addition, a quantitative eight-point post-project survey (1 = strongly disagree; 8 = strongly agree) was adapted from the Association of American Colleges and University (AACU) VALUE rubric, an assessment tool for liberal education, was administered to the undergraduate team to further examine the pedagogical value of the community-based research project. The undergraduates' indicated that the project was crucial in helping them achieve the four learning outcomes: Integrative and applied learning (95%), practical skills (95%), personal and social responsibility (89%), and intellectual skills (84%). Collectively, our results accentuated the importance of community-based research projects in supporting environmental science education. More importantly, this learning approach presents significant pedagogical value for higher education that warrants wider implementation and further evaluation.

Back to programme

(A342) PROMOTING SELF-DIRECTED LEARNING (SDL) AND ASSESSMENT AS LEARNING (AAL) IN SCIENCE EDUCATION IN HONG KONG

Chui-ling Tracy CHEUNG, *The University of Hong Kong*
Kai-yip Michael TSANG, *Yuen Long Merchants Association Secondary School*

Abstract
Learning and teaching in the 21st century witness great changes in terms of teaching pedagogies, learning environment and learners' diverse needs. In a typical science classroom in Hong Kong, students with mixed learner diversity are grouped into one classroom. Science teachers often then have to spend great efforts to cater for their needs: helping students be engaged and motivated to learn science in EMI environment, teaching students different language, cognitive and generic skills, as well as creating differentiated scaffold, tasks and materials. In particular, for successful and effective learning and teaching of science to take place, science teachers need to create highly challenging yet well supported science-learning activities to scaffold students' development of science knowledge, academic literacy and cognitive development (Gibbons, 2002). Conducting research studies on science literacy, language across the curriculum (LAC) and content and language integrated learning (CLIL) is crucial for application of innovative pedagogical approaches, particularly in educational contexts where English is not used as a first language like Hong Kong. Negligence on integrating content learning and language might limit Hong Kong students' development of 21st century skills, which is of utmost importance of their future career and academic advancement. In this study we address the issue of self-directed learning (SDL) in an EFL Science classroom as a way to provide language scaffold for Hong Kong students who are learners of Science using English as a foreign language (EFL learners). Our central thesis in addressing this question is how to bridge our students from a dependent learner to a self-directed learner by gradually releasing learners' responsibility (GRR) in a language rich support learning environment. This study thus aims to evaluate the extent of self-directedness in learning by monitoring the learning progress of students The research adopts a design-based intervention design with two groups of Secondary two (Grade 8) Science students in an EMI school in Hong Kong. One average academic ability class is invited as the intervention group while another class with similar academic ability is invited as the control group of this research study. Students in the intervention class receive additional language support and SDL elements in the teacher-researcher's lessons while students in the comparison class will receive no additional language support. Through the research period, language support used in the intervention group will be gradually removed by careful scaffolding in order to increase learners' responsibility (Fisher and Frey, 2013) and foster self-directed learning (Grow, 1991) to observe the learning progress of students. Academic achievements of the two groups are measured statistically through formative assessment tasks such as results in uniform tests and examinations. In addition, teachers' journals, questionnaires were also used to understand the attitudes of the teacher and students towards teaching and learning Science in English during the study. Results, pedagogical and theoretical implications for CLIL and SDL are discussed.

Back to programme

(A343) UNLOCKING SECONDARY SCHOOL STUDENTS' POTENTIAL FOR SCIENCE THROUGH MEMORY PALACE

Weicheng PUA, *Hillgrove Secondary School*

Abstract

Goals of the study: A major concern with students taking chemistry is that they are expected to recall, understand and articulate the reagents, conditions and observations (RCOs) of reactions. This acute jump in requirements often proved difficult for students. Students often struggle with the terminologies and related scientific information and because they lack the experiential processing skills when dealing with factual information in Science, students often do not know how to retain the information as long term memory. This makes assessment for learning at times, challenging. This is because one would not be able to differentiate students' inability to answer as a result of the inability to recall or as a result of misunderstanding or misconception. One of the possible interventions that can be employed could be the use of a constructed memory palace as a pedagogical tool. A memory palace, or the method of loci (MOL) is a mnemonic device that forms spatial relationships between the "loci" (physical structure and features in a location) and information to recall the learnings (Qureshi, 2014). The purpose of this study is to investigate the impact of memory palace on secondary school students in helping them to gain experiential processing skills when studying O-level Chemistry. The study also examines the pedagogical changes when implementing memory palace for O-level students. A previous intervention study was done on A-level students and had been presented in the Singapore Science Teacher conference in 2017. This study serves as a preliminary analysis of the viability of this pedagogy on its application in the secondary school context and syllabus. Methodology: This study employed a quasi-experimental approach whereby students were segregated into two intervention groups: memory palace (G1) and a conventional approach (G2). Students' knowledge gained were measured using pre and post test scores related to a topic. Qualitative survey was employed to draw out students' levels of engagement after the intervention. Implications & Significance: The use of memory palace as a pedagogical tool have proven to be useful for secondary school students as well. Qualitative feedback from students involved in the experimental group revealed the importance of having some processing structure that allows students to make meaning out of abstract information. Meaningfulness of these information becomes something that the students see as important and therefore allow the information to make an in-road into their long term memory. Teachers therefore ought to think about the pedagogical strategies that one can employ to allow students to make meaning out of all the information. The presenter will share how to employ memory palace for secondary students, using physical classroom and the actual school environment to organise information and create a memory palace that empowers students to remember. Future directions of this research as a long term pedagogical tool will also be presented.

Back to programme

(A344) DESIGN AND EVALUATION OF STEM TASKS RELATED TO BIOLOGY

Dominic KOH, *National Institute of Education, Nanyang Technological University, Singapore*
Aik Ling TAN, *National Institute of Education, Nanyang Technological University, Singapore*

Abstract
STEM is an acronym for Science, Technology, Engineering and Mathematics. STEM education has existed for some time, starting out with the intention to prepare graduates to work in the science and technology related fields to boost the country's economy and maintain its competitiveness (Banks & Barlex, 2014). It is a familiar term but there has not been a clear consensus on what it really means. For some, STEM is regarded as simply referring to science and mathematics (Bybee, 2010), and there is little understanding of how it is carried out in classrooms. In spite of the ambiguity, as mentioned by Bybee (2010), STEM education is valuable as it promotes learning of 21st century skills such as problem-solving and with many challenges faced by students being predominantly STEM-related, equipping students with knowledge of STEM disciplines would benefit them. It is noted that engineering, the 'E' of STEM, "provides a context for problem-solving skills" (Roehrig, Moore, Wang, & Park, 2012) as engineering involves identifying a problem, understanding it and then designing a solution to solve it. Furthermore, engineering utilises knowledge from different disciplines during its design process, allowing students to see how knowledge from different domains are integrated into solutions to solve problems. In Singapore, there has been efforts at bringing STEM to schools. For example, STEM is practiced as applied learning in some schools and the Science Centre has a unit called STEM Inc. that aims to promote STEM to science teachers in schools. STEM is not commonly integrated into the core science or maths curriculum. Given the promises of good educational benefits that STEM brings, it is imperative that STEM ideas should be practiced more in the core science curriculum. As such, this study aims to craft STEM related activities to enable biology teachers to bring STEM ideas into biology learning. This study is divided into two phases. The first phase is the developmental phase and it involved the design of three tasks to teach students this inter-disciplinary thinking process and apply to problems related to topics covered in the 'O' Level Biology syllabus using a Sense-Making model (Schwarz, Passmore & Reiser, 2017). The three tasks are based on the concepts of insulin delivery in diabetic patients, pill coating in drug delivery systems, and design of farming systems for optimal plant growth. The tasks require the students to ask questions, frame an issue, design a prototype to solve the problem, craft an explanation and evaluate ideas presented by peers. These tasks will be trialled with a class of forty Express stream secondary students. To evaluate the gain in science conceptual understanding a pre- and post-assessment is administered. Besides the assessment, scaffolded reports used by students to document their thought processes and ideas will be analysed for indications of thinking like an engineer. Interviews with selected students will be used to show how these tasks helped in their learning. The data collected would provide a clearer perspective on the potential for these tasks to become part of Singapore's core science curriculum.

Back to programme

(A352) EXAMINING THE POSITIONALITIES OF A TEACHER TEACHING IN LOWER TRACK SCIENCE CLASSROOMS

Meixue Michelle ONG, *Serangoon Secondary School*
Tang Wee TEO, *National Institute of Education, Nanyang Technological University, Singapore*

Abstract

To gain a better understanding of issues of science teaching in lower track classrooms, positionality is adopted as a critical and theoretical lens to understand how teachers could be positioned by their own beliefs, identities and lived experiences, thus influencing the actions they undertake in the classroom (Barton, 1998). This study seeks to identify the factors which shape the positionalities of a teacher and understand how these positionalities may influence pedagogical practices, classroom management strategies and teacher-student relationships. Through a case study approach, a secondary school physics teacher, with about thirty years of teaching experience, was selected for the study. The data sources for this study were drawn from a larger project which involved 39 Singapore public and co-ed schools and 247 classes. The case study involved two schools and four Normal track classrooms per school. The physics teacher was teaching in one of the case study classrooms. Selected lesson videos, interviews with students of the selected teacher, and the interview with the teacher contributed to the data sources for this study. This study is focused only on the political and relational positionalities of the teacher. These two prescriptive categories were used in the coding of the teacher interview transcript. From the coding process, it was found that under the category on political positionality, two sub-categories emerged from the data: 'consciousness-of-the-self' and 'consciousness of structures'. 'Consciousness of structures' refer to school structures and 'national structures', such as national criteria for lateral transfer between tracks. 'Consciousness-of-the-self' refer to the teacher's own perceptions of lower track students and perceptions of the traits of teachers suited to teach lower track students. Family and schooling backgrounds emerged as factors shaping the relational positionality of the teacher. The findings illuminated how teachers' political positionalities could be shaped by a consciousness of structures-institutional hierarchy, method of deployment of teachers, criteria for lateral transfer of students between tracks, and requirements and expectations of the national science curricula for the different tracks. However, as shown in the case study, there is a likelihood for teachers to exhibit less political awareness of their perceptions of lower track students, such as them being lower in academic ability, and having poor attitudes and low expectations towards their studies. Teachers could also hold views about the attributes needed of teachers to be able to handle lower track students. Furthermore, teachers' relational positionalities could be shaped by their respective personal histories. In sum, the above factors, which influenced the political and relational positionalities of the teacher, may have accounted for the curricular choices and the classroom management strategies adopted, as well as the extent of teacher-student relationships. The conflict between the various positionalities of a teacher and what the national science curriculum advocates may potentially disadvantage the lower track students' experiences with science in school. Implications for school leaders and key school personnel, for the professional development of teachers, and for researchers will be discussed. The limitations of the study and recommendations for future research directions are also discussed.

Back to programme

(A354) NURTURING SCIENTIFIC LITERACY FOR ALL UNDERGRADUATES VIA SCIENCE CLASSICS

Kai Ming KIANG, *The Chinese University of Hong Kong*

Abstract

Nurturing scientific literacy for everyone, not just for science students, has been one of the focuses in educational reform in the recent decades. While scientific literacy has various definitions, there are two important dimensions: one is on the understanding of the science and technology enterprise and its relationship with the public; another is to develop generic skills and knowledge, such as critical thinking skills and self-learning skills. These two dimensions can be considered as crucial knowledge and skills that every responsible citizen in the 21th century should obtain. However, it is often a challenge to design a curriculum for nurturing scientific literacy that serves the needs of both science and non-science students. On one hand, non-science students would usually found the quantitative aspects of science daunting and boring. On the other hand, teaching only the qualitative aspects of the nature of science may not necessarily be appealing to the science students. The diverse needs are widened further for higher education settings as their prior knowledge are even more specialized. In this paper, we suggest that reading science classics and discussing about them can be a suitable middle ground for putting these two extreme kinds of students together in a compulsory course that aims to nurture scientific literacy for several reasons. First, science classics encompass enduring questions that are common to all human beings, regardless of their disciplines and backgrounds. Second, science classics provide opportunities for the students to explore the relationship between science and the livings, cultures and religions of the society. Third, reading science classics develop an awareness of great people and great ideas, which is in itself a strong enough reason to demand those students having no interest in science to participate. Fourth, using primary literature has unique potential to instruct students on the nature of scientific reasoning and communication. We evaluated the effectiveness of such a classics-reading course. The sample consists of the students who studied the compulsory course In Dialogue with Nature offered by the Chinese University of Hong Kong that aims to nurture scientific literacy for every undergraduate, including both science and non-science students. A total of 1823 students were successfully tracked. The performance of the students is evaluated by the entry and exit surveys as well as their academic grades. Factor analysis is used to extract hidden factors. Samples are then divided into students of science and non-science background for further analysis. The result is that both the science and non-science students have gained significantly in all the factors related to the intended learning outcomes of the course. The non-science students, in particular, close the gap from the science students in their appreciation and understanding of science significantly. This is encouraging as it is often the case that, the non-science students are considered to be harder to nurture. The whole study seems to support the view that cultivating scientific literacy for every students in higher education setting can be achieved via the classics reading approach.

Back to programme

(A363) HOW A BEGINNING SCIENCE TEACHER DEAL WITH PRACTICAL WORK: AN EXPLORATIVE STUDY THROUGH THE LENS OF IDENTITY

Bing WEI, *University of Macau*

Abstract

The initial years of teaching, or the induction period, has proved to be the most difficult stages of teachers' careers. This is the time that novices strive to adapt ideas from teacher preparation programs to the realities of classrooms and school contexts and the time that they learn to socialize into the culture of the school to form new identities of practicing school teachers. As a matter of fact, a series of research studies have revealed that teachers deal with many difficulties during the induction period, including discipline and classroom management, contextual contradictions, poor administrative support, limited resources, lack of time due to an overloaded schedule, and contradictions between theory and practice. Practical work has constituted a special challenge for beginning teachers in science subjects, especially when scientific inquiry is emphasized in recent reform-driven curriculum. Given that the enactment of practical work interrelates with various factors, a comprehensive lens is needed to examine teachers' enactment of practical work. Through the lens of teacher identity, in this study we use Zheng (a pseudonym) as a case to explore how the interactions between his identity as a beginning physics teacher, the school context, and his personal dispositions influenced his actions in dealing with practical work during the first two years of his teaching career. The research question that guided this study is: how does Zheng view, represent himself, and act within a specific school-context when dealing with practical work? This study is helpful for us to understand beginning science teachers' professional development related to practical work in general and scientific inquiry in particular in school context. We explored how the interactions between his identity, the school context, and his personal dispositions influenced his actions in dealing with practical work during the first two years of his teaching career. Various kinds of data were collected over a period of ten months of study: 3 semi-structured long interviews, 26 classroom observations, 32 brief interviews as well as various artifacts and lessons plans. Four main categories emerged through the analysis of the data that represent the main features of the participant's identity as a beginning physics dealing with practical work: (a) personal characteristics; (b) sense of agency; (c) contextual constraints; (d) ongoing interpretation of experiences with practical work. These findings are presented through authentic extracts and quotes from the data. The interaction between the 'personal,' 'social,' and 'situated' aspects rendered Zheng to continually interpret his experience with practical work. His inherent enthusiasm, perceptions of the roles of practical work in science learning, instilled education on scientific inquiry provided positive influences on his interpretation and reinterpretation of his experience and identity. More importantly, his sense of agency with practical work played a critical role in the process of his interpretation and reinterpretation.

Back to programme

(A365) EPISTEMIC APPROACHES TO PROBLEM-SOLVING IN DESIGN-BASED INQUIRY ACTIVITIES

Timothy Ter Ming TAN, *National Institute of Education, Nanyang Technological University, Singapore*
Yew-Jin LEE, *National Institute of Education, Nanyang Technological University, Singapore*

Abstract
Purpose: In the context of problem-based and inquiry learning, problem-solving (PS) is a complex skill requiring the learner to think in order to overcome the gap in what they know in order to attain a particular goal. In inquiry science activities, the premise is that invoking such PS thinking leads to the learning of science and the development of a scientific literacy. But does it? Do students adopt "scientific" approaches, applying science knowledge and using scientific processes to solve problems, or do "engineering" trial-and-error and optimisation approaches predominate? In order to examine this, a heuristic framework and taxonomy was developed to examine the epistemic approaches adopted by students in integrated science, technology, engineering and mathematics (STEM) laboratory activities that feature a design-based inquiry (DBI) approach. Design and Methodology: A novel curriculum package was developed around activities that blend inquiry science learning with an engineering design challenge involving the microbial fuel cell (MFC). The novel curriculum was co-developed with and conducted by experienced teachers from a government-aided secondary school in Singapore, and implemented as a 10-week program with two groups of Secondary Two students (n = 77). This MFC program was studied using qualitative methods in order to examine its effectiveness as an approach to the cross-disciplinary teaching of science, and the development of aspects of scientific literacy. A key aspect was to focus on describing the approaches students take in PS, in order to examine the affordances of the program for the development of PS skills. The EPiSTEMIA Framework developed for this describes four epistemic approaches to problem-solving derived from a 2x2 matrix of the scientific-engineering conceptual approach dichotomy in one dimension, and the constructor-critiquer (Ford & Forman, 2006) social role dichotomy in the other. Findings: The curriculum was well-received with strongly positive feedback from students. Minds-on student learning in the conceptual, epistemic, and social domains of scientific literacy were observed. In particular, students applied evidence-based reasoning and a variety of problem-solving approaches to the learning tasks. In different task contexts (generative/hypothetical versus critique/feedback), student groups appeared to vary their collective epistemic approaches depending on the task. In the former, student groups' responses tended to cluster in engineering-constructor approach, whereas a broader spread across scientific-engineering and constructor-critiquer dimensions was noted for the latter. On the other hand, individual students appeared to overwhelmingly adopt a single approach, at least in investigative and design-based tasks, i.e. students who adopted the scientific-critiquer approach tended to do so consistently during such tasks. Value and Implications: The development of scientific literacy in the learner remains an ongoing endeavour with many issues to overcome. There is also a paucity of the appropriate teaching tools and pedagogies to fully realize that goal. In addition to being the first successful implementation of a DBI-based, STEM-integrated MFC curriculum in support of this goal, it is

hoped that this project's examination of students' epistemic approaches to problem-solving in inquiry learning activities may go some way towards the understanding and hence fostering of PS skills in science education.

(A366) THE USE OF SCIENCE NOTEBOOKS FOR SCIENCE ACTIVITIES IN PRESCHOOL EDUCATION

Elena CALDERÓN-CANALES, *Universidad Nacional Autónoma de México*
Leticia GALLEGOS-CÁZARES, *Universidad Nacional Autónoma de México*
Fernando FLORES-CAMACHO, *Universidad Nacional Autónoma de México*

Abstract
Science learning is an active and continuous process through which students take information from what surrounds them to build personal representations, in turn, in science activities students build an understanding of how science works, and the use of records or taking notes is a fundamental part of this activity. Science notebooks in science activities are tools in which students can capture their way of seeing and understanding natural phenomena, as well as constructing and reconstructing their representations. In turn, these records serve as external memories in which students can include conceptual and procedural elements that have been significant throughout the activity. Also, science notebooks promote research and promote observation, reading and writing skills in students, as well as boosting emergent writing skills. Although the use of science notebooks in preschool is infrequent, there is evidence that suggests that children of this educational level have reasoning and comprehension skills that allow them to participate and benefit from activities that incorporate scientific practice and the use of records. From this context, the goal of this research was to analyze the use of science notebooks used by preschool students (4 to 6 years of age). Methodology: The notebooks are individual materials that were designed as part of a sequence of activities about the subject of sound for this educational level. Prior to the use of the notebooks, a training course was held with the teachers so that they would know the activities of the sequence and the use of the notebooks. The science notebooks of 25 preschool students were analyzed. All the notebooks were photographed for analysis. To analyze student records, a checklist with indicators was developed to evaluate the activities (follow instructions, complete the registration, type of information, type of context and incorporation of symbols) and to qualify the drawings (labelling, scale and, details). A total of eight activities were recorded, each one was evaluated with the aforementioned indicators. Findings and discussion: The results of the analysis show that 87% of the students followed the instructions and completed all the proposed activities. The most used input was "description of the activity" (51%) and context they most refer to has to do with the activity carried out (65%), That is, children register elements of the immediate experience of the activity, also 23% add elements as examples and links the activities with their context of daily experience. It was also observed that 93% do not incorporate symbols or label their drawings and 53% add disproportionate drawings and with few details (58%). Implications: The use of science notebooks was a useful tool for students to express their ideas, communicate and share with others, and also provided information on the understanding that students are achieving about the phenomena that were addressed in the activities. It is fundamental to consider including this type of tools from this educational level to promote in the students not only a better conceptual understanding but also to promote the development of procedural, observation and reading and writing skills.

Back to programme

(A367) EFFECTS OF SCHOOL SCIENCE LABORATORIES WITH ICT ON HIGH SCHOOL STUDENTS' REPRESENTATIONS OF SCIENTIFIC KNOWLEDGE IN DAILY SCHOOL CONTEXT

Fernando FLORES-CAMACHO, *Universidad Nacional Autónoma de México*
Leticia GALLEGOS-CÁZARES, *Universidad Nacional Autónoma de México*
César ARIAS-NAVARETTE, *Universidad Nacional Autónoma de México*

Abstract
The present research paper has as main purpose to answer if the technological resources have any influence over the students' information understanding when the applied resources are not in a specific experimental class situation and are only based on the professors' technological capabilities and their own pedagogical content knowledge, representing different proficiency levels of technological resources and diverse educational approximations to the use of ICTs in high-school science laboratories. Methodology: The present study was carried on two conditions: In the first, 285 high-school students from public school systems that fulfill the condition of taking the courses of biology or physics in ICT laboratories. In the second, 378 students that were taking the same courses in traditional laboratories that did not use any ICT resources. For both cases, rather than specific interventions over students or professors; the acquired data was based on their everyday experiences in the students' schools and courses. In order to collect the data a questionnaire based on an integrative knowledge in four representational levels was designed, validated and applied to the students. With the gathered data quantitative analysis was performed (variance and principal components analysis) along with a qualitative analysis on the external students' representation (graphs, draws, descriptions, conceptual maps, etc.). Results and Discussion: The quantitative results show relevant developments in the comprehension of topics related to the field of genetics from students on the ICT laboratories, opening new learning capabilities and representation possibilities. In the case of forces and movement, although students show some advance in the understanding of Newton's third law and the representation of how force behaves through time, the results are less significant than in the case of topics related to biology. The qualitative analysis demonstrate that the incorporation of ICTs helps students to improve the external representations that they make, including more relations between the concepts and processes related to genetics and physics; specifically, a graphical representation of the genetic material in diverse organizational levels and a graphical representation of the interaction processes within time. The described data and analyses express that the introduction of science laboratories in schools with a variety of technological resources favour an enriched multi-representation environment, spatially with simulations and sensors, that positively influence over the comprehension and representational possibility of students independently from the didactic strategy that the school or professor use. Implications and relevance: The present study establishes the hypothesis that a relevant factor to account in ICT laboratories is the possibility that students have to interact with multiple representations. The results show that this is a relevant factor in the case of biology and physics courses opening new questions for research as the differences between results in biology and physics learning and representing. By improving the possibilities of multi-representational use through ICTs we expand science learning.

Back to programme

(A368) PHYSICS LEARNING THROUGH THE USE OF PROGRESSIVE MULTIPLE REPRESENTATIONS

Leticia GALLEGOS-CÁZARES, *Universidad Nacional Autónoma de México*
Fernando FLORES-CAMACHO, *Universidad Nacional Autónoma de México*
César ARIAS-NAVARETTE, *Universidad Nacional Autónoma de México*

Abstract
The current paper analyses physics concepts comprehension in high-school students under a multi-representational class context by comparing student groups with relevant differences in the way teachers apply representations from different digital resources to a physics class to understand the topic of forces and movement in collisions. Methodology: A three phases intervention strategy was designed and applied in public high school. Phase 1, teacher explains and describes the topics of graphics, equations and descriptions in a schoolboard; phase 2, teacher is focused in the use of simulators, experimental activities and use of traditional described resources; phase 3 teacher adds to phase 2, sensors and graphics in real time and videos for the measurement of objects' movement. Each phase was applied to a different school group (N=92) with the same professor, avoiding the introduction of new variables. The results data was obtained from a previously validated questionnaire. In order to identify the conceptual comprehension and the symbolic and graphical representation characteristics that students made, previous, during and after on collision case, a specific rubric to evaluate that representational characteristics was designed. The data was categorized and analyzed by a variance analysis and a qualitative analysis of students' physical descriptions, use of symbols and graphical representations. Results and discussion: Significant differences were found between the phase 3 and phase 1 groups; however, no substantial variances were found among phase 2 and phase 1 students. Phase 3 students have a better understanding of the objects acceleration in the collision ($F = 15.07$; $p = .000$) and the comprehension of Newton's third law ($F = 3.862$; $p = .026$). Groups of phases 1 and 2 persist on common previous ideas; such as: the effect of crash depends on the objects' weight ($F = 11.593$; $p = .000$) and arrow representations of diverse physical entities (force, velocity and acceleration) without proper identification ($F = 4.445$; $p = .015$). From the graphics of force through time it is noticeable that phase 3 group manage to describe an impulsive force, while phases 2 and 1 groups confuse a force behavior with objects' trajectory. It is noteworthy to mention that although phase 2 group had an intensive use of simulators, it presents great similarities with phase 1 group. Implications and relevance: The present study implies that the use of multiple representations for science learning requires a progressive process in the matter of type and quantity of digital resources that will probably need certain threshold in order to be effective for students. The results support the use of ICTs classrooms and laboratories, which are currently growing in use. However, such use should be in a structured way with a progressive use within levels of difficulty depending on the level and type of representations.

Back to programme

(A370) DEVELOPING GRADE 9 STUDENTS' CREATIVITY AND INNOVATION SKILLS FOR THE 21ST CENTURY USING STEM EDUCATION IN BIOLOGY SUBJECT

Chalongwoot JANHOM, *Kasetsart University*
Chulaporn TONGSRINUT, *Horwang School*
Jeerawan KETSING, *Kasetsart University*

Abstract
Creativity and innovation are acknowledged to be one of the key 21st century skills for the workforce success. Thus, promoting these skills in basic education is essential for preparing future citizens to live harmoniously in knowledge-based society. According to Partnership for 21st Century Learning (2015), creativity and innovation skills are referred to cognitive and mental abilities of a person who can (1) use a wide range of techniques to create new ideas; (2) generate 'out of the box' ideas; (3) refine and evaluate the ideas; (4) communicate the ideas effectively with others; (5) be open-minded and responsive to new perspectives; (6) understand real world limits; (7) view failure as a room for self-improvement; and (8) produce product from the creative idea(s) that benefits other members of society.

Recently, STEM education has been highlighted in science standards and curricula of many countries. In Thailand, the *National Science Indicators* (MOE, 2017) suggests science teachers to employ engineering design process in science classroom. Though literature recommends that STEM education is likely to promote creativity and innovation, no empirical studies investigate the impact of STEM education on learners' creative and innovation skills. Therefore, this study addressed this issue. In doing so, we adopted 6Es STEM approach suggested by International Technology and Engineering Educators Association (2014) for teaching Biology. For example, in a topic of the genetic disorder, a class of ninth graders (27 girls and 20 boys) in a high school of Bangkok was cultivated to create an arm for helping Duchene Muscular Dystrophy (DMD) children eating problem. The class started with observing a DMD patient on video (Engage). The students then explored information of DMD pathology (Explore). Afterwards, the class discussed about how the DMD occurs and the patients' living difficulties (Explain). The children then designed Duch-arms to support DMD patients using the Tinkercad program and presented the designed models (Engineer). Students revised their models, invented the prototypes, tested the effectiveness of their prototypes, and improved it based on the outcome (Enrich). Finally, a product of each group was evaluated by teacher and an invited Engineer (Evaluate).

Data were collected from an open-ended diagnostic test. Results from content analysis show that most of the students have a better competency level on creativity and innovation after the STEM activities. Specifically, prior to the learning approach, most of the participants were at a novice level. However, after the learning intervention, the majority of children hold basic level. Typically, the students have a better understanding of the real world limits (78.72%). They can communicate their ideas effectively (76.59%). And they are open for alternative viewpoints (74.47%). Nevertheless, even after the STEM approach, a number of students still struggled to revise their ideas (78.72%). This study suggests that STEM is somehow able to develop students' creativity

and innovation skills. However, some skills are difficult to develop than the others. Science teachers should carefully pick up real life problems that perfectly fit with science concept, and it should not be too complex or less challenging for student level.

Back to programme

(A379) THE INFLUENCE OF ICT IN THE LEARNING OF GENETICS

Beatriz GARCIA-RIVERA, *Universidad Nacional Autónoma de México*
Fernando FLORES-CAMACHO, *Universidad Nacional Autónoma de México*
Leticia GALLEGOS-CÁZARES, *Universidad Nacional Autónoma de México*
Elena CALDERÓN-CANALES, *Universidad Nacional Autónoma de México*
Araceli BÁEZ-ISLAS, *Universidad Nacional Autónoma de México*

Abstract
This work shows the results of an analyses of the construction of external representations about Genetics in High School students in a class context with multiple-representations. Methodology. In order to identify the students' representations and know if these representations change or enriched after working in a learning context supported by multiple representations with ICT and, other didactic tools. Two groups of students were compared in two conditions. Condition A formed by students who worked the topic of Genetics with limited use of resources (readings, schemes, punnet square exercises, teacher´s presentations in power point), against condition B, integrated by students who used the same resources and others representation alternatives (conceptual maps, simulators, experimental activities) which promote the interaction of the students and their possibility of generating complex and diverse representations. Data was obtained from a questionnaire of 18 items (Cronbach's alpha coefficient of 0.88) previously validated. The sample was of 386 students from public High School. The questionnaires were evaluated with the same rubric used to validate the instrument. The rubric qualifies the answers to each question independently, assigning five values considering: the achievement in understanding the concepts, its use in solving problems or exercises about inheritance, and the level and external representations elaborated by the students. To determine the differences between both groups, a One-way analysis of variance (ANOVA) and Principal components analysis were used. Findings and discussion. The results show that the students who worked in enriched environments with multiple representations obtained the highest means in all the items (Condition B) with an average m = 3.27, while the mean in Condition A was m = 2.53. The students of condition B gave more complete descriptions and achieved greater precision in their graphic representations (drawings and schemes); the students who worked in classes with condition A achieved good results in written explanations, but not in graphic representations, nor in generating models to describe the genetic processes. The principal component analysis, generated four components: C1) includes answers that require a written justification from the establishment of relationships between concepts; C2) correspond those that require the use of graphic representations to generate explanatory models; C3) includes answers that describes the genetic information of the gametes and in diploid cells; C4) considers answers that explain the process of transmission of genetic characteristics between parents and children. Implications and significance. The findings of this research show important differences in the level reached in the representations of the students when they work in a context with resources and with specific activities that allow them to represent in different ways the phenomena addressed, they can distinguish more clearly the levels of organization of the genetic material; recognize and use different ways to symbolize the processes; establish links between different symbols; in general, greater understanding and integration of inheritance processes.

Back to programme

(A381) AN ANALYSIS OF THE LEVELS OF EXTERNAL REPRESENTATIONS ABOUT GENETICS IN HIGH SCHOOL STUDENTS

Beatriz GARCIA-RIVERA, *Universidad Nacional Autónoma de México*
Leticia GALLEGOS-CÁZARES, *Universidad Nacional Autónoma de México*
Fernando FLORES-CAMACHO, *Universidad Nacional Autónoma de México*
Araceli BÁEZ-ISLAS, *Universidad Nacional Autónoma de México*
Elena CALDERÓN-CANALES, *Universidad Nacional Autónoma de México*

Abstract

This paper shows the results of an analysis of the external representations that high school students (17 to 18 years old) elaborate about Genetic phenomena after using different didactic strategies that incorporate ICT. Methodology: To know the levels of representation that students can reach, three didactic strategies on Genetics were developed (SI, SII and SIII), the strategies share the same learning objectives but differ, in the use of didactic resources and digital technological tools that enable the use of diverse external representations. Each sequence was applied to a different group of students from a public High School in Mexico (UNAM). The sample was 186 students. After completing the didactical sequences, students answered a questionnaire of 18 questions, previously validated. The present analysis was made with the questions that required using external representations (drawings) to describe three themes: a) how genetic information is organized, b) genetic information in a haploid cell, c) genetic information in a diploid cell. A rubric was elaborated to evaluate the questionnaires to classify them in three representational levels: Sufficient, Medium or High. Findings and discussion: Results show differences among the three groups (SI, SII, SIII), students from SII and SIII reached the High level more frequently, while those of SI reached Sufficient level because they elaborated fragmented representations. About theme a), 13 students reached the High level (11-SIII and 2-SII), because they represented between four and five elements, from chromatin to nitrogenous bases; 21 students reached Middle level (10-SIII, 7-SII and 4-SI), because they represented from two to three elements in their organisation of the genetic material. The identification of a greater number of elements in the hierarchical organisation was an achievement that was reached mainly by those students who used SIII, while those of SI only came to recognize two or three. In the theme b), 19 students reached the High level (14-SIII, 2-SII, 3-SI) since they represented that the gametes are haploid cells, and 9 students (8- SIII and 1 from SII) represent with a letter the information for the expression of a characteristic in the haploid cells; while in theme c), 11 students reached the High level (10-SIII, 1-SI) because they represented with two letters the information for the expression a characteristic in the diploid cells. The fact that the students recognize that a haploid cell contains half of the genetic information may indicate that these students consider processes of cellular specialization. However, a persistent difficulty for all students is that they draw only the sex chromosomes without reference to any other. Implications and significance: The findings show that the use of activities and technological tools that promote the use of multiple representations allowed students to reach a better understanding and integration of the subject and elaborated complete and complex schemes and descriptions responding in terms of processes. It was also evident that, even with the use of ICT, difficulties persist in students' understanding, which provides

valuable elements of analysis that can lead to new proposals that support student learning.

Back to programme

(A382) 'VISIBLE THINKING' ROUTINES FOR THE SYNTHESIS OF CONCEPTS IN SCIENCE

Umay KHNG, *Raffles Girls' School (Secondary)*
Kian Hong YANG, *Raffles Girls' School (Secondary)*

Abstract
In the teaching of Science to Lower Secondary (ages 13 and 14 years old) students in Raffles Girls' School, Singapore, we find that students tended to regard what they have learnt in class as a series of information to memorize and processes to practice. Little time is spent to explore the links between the pieces of new knowledge, as well as between their prior understanding. Through the employment of 'Visible Thinking' routines in the classroom, we seek to habituate in students the synthesis of ideas and concepts in Science. This facilitates the shift in students from the rote learning of discrete scientific knowledge to a deepened conceptual understanding of a larger picture. From the book "Making Thinking Visible", we selected 'Visible Thinking' routines that encouraged students to link, consolidate and organise their knowledge, as well as heighten their metacognition. These routines were used repeatedly during our lessons. To understand the extent of their effect, we studied students' responses to the routines over two academic terms. We also gathered feedback from students through survey on their perception of these routines and their usefulness. We compared the responses of our students at different stages of the study and found that with regular usage of these 'Visible Thinking' routines in class, students were increasingly able to bring together multiple ideas surrounding the topics that they learn in class. For example, when learning about Separation Techniques, students were able to discuss concepts using ideas about elements, compounds and mixtures. They were also able to assimilate ideas from the Scientific Method to the other chapters taught subsequently. Additionally, it was observed that students became clearer in their articulation of gaps in their understanding. Based on data from our survey, we noted that students found that with increased usage of thinking routines, they had greater inclination to look at new knowledge conceptually. The repeated use of 'Visible Thinking' routines allowed students to acquire skills to build conceptual understanding in Science. The routines also highlighted gaps in students' understanding, which can then be addressed by teachers. Hence, we believe that it is beneficial for Science teachers to incorporate 'Visible Thinking' processes in their lessons. This entails the regular use of these processes and not simply a one-off session. Curriculum time has to be used to explain these processes, but practicing these routines can be done by students outside the classroom. This would also give students the space for deep thinking. In this presentation, we will share how these thinking routines were incorporated in the teaching and learning of Science in our classroom, as well as discuss our observations during the course of this study. The introduction of 'Visible Thinking' routines in their early years of learning Science has the potential to shape how students view Science and the learning of Science. Through the use of these routines, students' energy is directed towards concept building rather than rote learning. With that, students can become active participants of their knowledge construction instead of mere recipients of scientific knowledge.

Back to programme

(A384) A COMPARATIVE CASE STUDY OF THE IMPLEMENTATION OF ACTIVE LEARNING RESOURCES IN FOUR DIFFERENT SOCIO-POLITICAL CONTEXTS: THE UNITED STATES, CHILE, MEXICO AND COLOMBIA

Marjee CHMIEL, *Howard Hughes Medical Institute*
Rodrigo TAPIA, *Biomedical Neuroscience Institute*
Javier ROBALINO, *Howard Hughes Medical Institute*
Gonzalo PEÑALOZA, *Maloka Science Center, Bogotá*

Abstract

Research on active-learning in science has shown evidence of improvements in student attitudes, writing, thinking and conceptual understanding. However, quality educational resources and teacher professional development supporting active-learning remain sparse, and fidelity of implementation is challenging to achieve. As such, the science education field has been examining the larger question of how active-learning can be adopted and supported at a scale that provides access to all students. The goal of this study is to follow the implementation of free, online resources that support active-learning in four different socio-political contexts to illuminate patterns of similarity and divergence leadings to a user-centered theory of change for active-learning implementation. This paper focuses on the implementation of a collection of resources addressing natural selection found on BioInteractive (www.hhmi.org/bioInteractive), a respected resource for free, online science learning media. BioInteractive resources were developed primarily for a U.S. educational context, but it has global usage. Data collection and analysis for the case study is anchored in two theoretical frameworks. Guskey's levels of teacher professional development provide an understanding of participants' reactions, learning, organizational support, and use of new knowledge and skills. These data are collected via pre-post surveys from teachers with specific teacher populations in each case commensurate with national populations. For student and teacher knowledge, we used both open and closed-ended validated instruments to measure teacher and student changes in content knowledge specific to natural selection. Findings indicate positive growth in knowledge, skills, and attitude and this translates into student knowledge and attitudes, but this is only part of the story, as teachers inevitably modify the resources and strategies given to them. In this respect, we argue that a case study approach adds important context about what teachers actually do with these resources. Exploring this delta between intent and achievement is critical for understanding implementation. In order to capture an understanding for how active-learning resources are modified by teachers during implementation, we use design-based research (DBR) as a lens to analyse how teachers adapt and co-create the resources. DBR provides a lens to translate local contexts into theory. These data are collected through classroom observation protocols and artifacts including lesson implementation plans, lesson longs, and student work. Here, data indicate revealing patterns of implementation challenges as well as "fits and starts" that help conceptualize a lifecycle of active-learning implementation. This case study capitalizes on the fact that in 2015, BioInteractive's international reach made an important advancement through establishing more formal international partnerships for implementation in three Latin American countries: Mexico, Chile, and Colombia. Each of these countries are undergoing distinct science education reform movements, however, all include a focus on active-

learning. Educational resources and professional development to support active-learning are being invented and reinvented throughout pockets of the globe, but actual implementation is not straightforward. Teachers adapt what they are given to suit local needs. By examining these adaptations across different socio-political contexts, we construct a realistic and resilient understanding of how active-learning goes from a globally good idea to an idea that does global good.

Back to programme

(A386) THE FACTORS OF PRE-SERVICE TEACHER TRAINING PROCESS TO CREATE ACTIVE LEARNING IN TEACHING SCIENCE: CASE STUDY THE PRE-SERVICE SCIENCE TEACHERS IN THAILAND

Ruhaisa DEARAMAE, *Khon Kean University*
Jiradawan HUNTULA, *Khon Kean University*

Abstract
Students' learning in science classroom depend on teaching activity of their teachers. Actually, teacher center of teaching style is easy for made it happen in class but it be trouble for students in learning. It is very important to embed in mine of in-service teachers to construct actively activity in class, since they were pre-service teacher. Therefore, the aim of this study was to find the factors of pre-service teachers training process to create active learning professionally in teaching science in Thai context. We used a case-study research and selected four pre-service teachers to be case study by selecting from their performance in micro-teaching since they were studying in the 4th year of study. There were two groups of them, one was a group of good performance and the another one was not. When they were pre-service teachers, studying in the 5th year of study, they have to practice in school for one year. To find the factors of training pre-service teachers, all of them were observed and interviewed. The data was collected by documents analysis, classroom observations and semi-structure interview. Then, the data was analysed and interpreted based on characteristics of active learning and used the triangulation to control the quality of this study. The results showed that four pre-service science teachers provided the students to observe, discuss and analyse scientific contents before their answers the question. Furthermore, they encouraged the students to do activities with interpretation collaboration work, brainstorming in within group and self-learning in doing the activities. Some of them taught students to do experiment and provided students to do experiment by themselves. Moreover, at the end of teaching and learning in science classroom, all of pre-service science teachers encouraged the students to present the outcomes of their learning to their classmate. We found that the teaching of four pre-service teachers related to characteristics of active learning which are: 1) students participated in the learning more than listening; students are interpretive and cooperative work, 2) students developed skills by doing by themselves, 3) students are involved in higher order thinking, 4) students are engaged with learning activities; writing, brainstorming, observation, presentation and discussion, and 5) students are explored with their attitudes and values (Bonwell & Eison, 1991). In addition, the semi-structure interviews results from four pre-service teachers and their supervising teachers showed that there were four factors of effectiveness processes to train pre-service teacher as following: - Observation of teaching and learning: observe their friends' class - Question of teaching and learning: practice in constructing the questions to ask students interactively - Discussion of teaching and learning: create lesson plan with discussion group and – Refection of teaching and learning: receive the feedback after their teaching

Back to programme

(A387) STUDENTS` CONCEPTIONS OF THE NATURE OF SCIENCE: A PILOT STUDY OF AN "ACT A SCIENTIST TEST"

Jaakko TURKKA, *University of Helsinki*
Maija AKSELA, *University of Helsinki*

Abstract
Goals and significance: Nature of science (NOS) is an important issue in science education. The understanding of NOS entails exploring the image of a scientist with tests such as Draw a scientist -test (DAST). However, DAST is criticised for not giving a complete array of students' conceptions (Reinisch, Krell, Hergert, Gogolin, & Krüger, 2017). The image of a scientist could be complemented with further art integration (Turkka, Haatainen, & Aksela, 2017) such as mimicking, role-playing or other drama activities that can engage students with NOS (Ødegaard, 2003). The goal of this study is to design a drama-based Act a Scientist –test (AAST) to assess students' conceptions of NOS. Methodology: A pilot of AAST, as described below, was conducted for 28 bachelor-level science students. Their NOS conceptions were analysed with deductive content analysis based on a reconceptualised model of NOS (Dagher & Erduran, 2016). The model implies a range of a scientist actions within cognitive-epistemic - and social-institutional domain, which are embedded in institutional, political and financial systems. Findings: In AAST students write down actions that they assign for a scientist and mime these actions for their peers who try to guess the mimicked actions. If the peers get an action right, the actor moves to a next one. Students represent their NOS conception through writing, acting and speaking, all of which can be assessed. In the study, 89 scientist actions were found. The more frequent actions were thinking, experimenting and writing, which were categorized to cognitive-epistemic domain. The less frequent actions covered various aspects of a scientists' life, such as having a meeting, networking and asking for money. These were categorized to social-institutional domain of NOS. Outside these were actions such as a scientist gets confused, frustrated or inspired. These were assigned to emotions category. Discussion and implications: The wide range of actions in AAST indicate that the test enables expression of scientist actions in the different domains of NOS and in the domain of emotions making it a prospective test for NOS conceptions. The prevalence of cognitive-epistemic actions in this study can be explained by the stereotype of a scientist, either unconsciously repeated or purposefully used as a tool for non-verbal communication. The AAST can be developed by changing instructions: acting in groups could bring out more social-institutional actions. More research is needed to validate and develop the test.

Back to programme

(A388) GENERATING OF SCIENTIFIC EXPLANATION: THE EFFECTS OF GENERATE AN ARGUMENT INSTRUCTIONAL MODEL ON NEWTON' LAWS CLASSROOM

Saksit HEMKAEW, *Demonstration School of Ramkhamhaeng University*
Pannida MEELA, *Demonstration School of Ramkhamhaeng University*

Abstract
Generating of scientific explanation is an important skill in learning science subject in order to use scientific claims, evidences and reasoning to demonstrate students' understanding of certain situations. Accordingly, teaching science by applying Generate an Argument Instructional or GAI model is an approach to encourage students to develop scientific explanation by generating and revising the scientific explanation through GAI model procedures. This model is designed to provide an opportunity for each groups of students to develop a claim that answers a question based on an available data set. As part of this process, groups create a tentative argument that provides this claim and the evidence that supports in a medium that can be viewed by others. Each group then has an opportunity to share their ideas during an argumentation session. At the end of the argumentation session, each team has an opportunity to revise their initial argument in order to make them better. This stage of the model helps students learn how to argue from evidence and how to evaluate and communicate information in science. This study aimed to investigate the effect of using Generate an Argument Instructional or GAI model on the ability to generate scientific explanations which is a significant element in learning science subject for secondary level education. The scientific explanation performance test with reliability at .86 was administered to 42 of grade 9 students who studied in a science class at a demonstration school in Thailand. The scientific explanation performance test has six items each items covered Newton's Law of Motion. All test items required students to explain the three components of scientific explanation – scientific claim, evidence, and reasoning. The researcher created the criteria for assessing students' scientific explanation scores. The quality of the evaluation criteria was assessed by using inter-rater reliability. The data collecting of scientific explanation divided into two steps; Firstly, teachers prepared student to understand in the method of scientific argument and the role of the student in teaching after testing by the pre-test of scientific explanation performance test. Lastly, enhancing the GAI model into the classroom and test them again by the same test. The data were analysed by using mean scores, standard deviation, and compare mean by using paired sample t-test. The findings revealed that the students significantly improved in the ability to explain all components of scientific explanation ($p< 0.05$). Finally, students were interviewed by using a semi-structured interview. Most students have the same opinion that GAI model can help students refine their explain the phenomenon and develop their communication and presentation skills. Therefore, it can be concluded that applying Generate an Argument Instructional or GAI model enhanced students' ability to generate scientific explanation for learning scientific conceptual . For the next research, we believed this model can be used to improve the skills of other students.

Back to programme

(A390) PSYCHO-SOCIO AND BIOGRAPHICAL VARIABLES: SCIENTIFIC APTITUDE AND SECONDARY SCHOOL STUDENTS

Dayal PYARI, *Amity Institute of Education*

Abstract

Today we are living in a scientific world and science has permeated each and every aspect of our life. Science education; therefore is inevitable need of the hour. In the world of technology, each individual is influenced by science, every vocation is related to science and even teaching is most influenced by technology. Science is one of those human activities that man created to gratify certain human needs and desires. Science is valued mostly for its practical advantages though it is also valued for gratifying disinterested curiosity and as an object of great aesthetic charm. It is quite obvious that the bulk of mankind value science, chiefly for the practical advantages it brings with it. It will be futile to prepare separate case for the inclusion of science in the curriculum because the reasons for its inclusion are exactly the same as those for the inclusion of subjects other than science though it has been given a core place in the curriculum because of some special values provided by science only and not by any other subject. All the school subjects are taught because they provide liberal education; they are the part of the equipment and preparation for life which we expect the school to give to its pupils so that they may play their part in the community as intellectual citizens. Science takes its place side by side with other subjects as an essential element of one's education. It affords knowledge of certain facts and laws and an insight into methods and data peculiar to the domains of science. Various commissions have recommended science education from time to time. The aim of this study is to investigate the effects of scientific aptitude of secondary school students to promote their Science Interest, Study Habits, Cognitive Style, Academic Achievement, Scientific Creativity, Academic Achievement Motivation, Delay of Gratification, Task Persistence, Science Methodology, Science Achievement, Socio Economic Status, School Environment and Home Environment. In the present study Ex-Post-Facto method of research is used. In Present study psycho-socio-biographical variables have already occurred and only their dependent variables (scientific aptitude) remain under research observation and analysis i.e. the independent variables (Psychological, social and biographical) have been studied in retrospect for their possible relation to and effects on the dependent variable (scientific aptitude) since none of these independent variables under study are subject to direct manipulation and are manipulated through selection only, hence Ex-Post-Facto method of research has been followed. The research includes a pre- test post -test research with a control group. The subjects of the research consist of 1500 students reading at 10th grade of secondary schools exiting in Agra, India. The data collection tools for the research includes the 12 tools in which two tools were made by researcher. As a result of the research, it was determined that contribution of some psychological, social and biographical characteristics of secondary school students to the total predicted variance in scientific aptitude. The psychological variables under study were science.

Back to programme

(A391) STUDENT-QUESTION-BASED INQUIRY IN SCIENCE EDUCATION

Jaana HERRANEN, *University of Helsinki*
Maija AKSELA, *University of Helsinki*

Abstract
Goal and significance of the study: The goal of this systematic review study is to review the use of students' own questions in inquiry-based science education (IBSE). In existing inquiry models, students' questions are used in open inquiry (Banchi & Bell, 2008), in which the learner carries out all inquiry phases, including formulating research questions. Use of open inquiry has however been criticised (Kirschner, Sweller & Clark, 2006). This review takes into consideration other inquiry teaching practices besides open inquiry, and thus aims to create a model on the use of students' own questions in inquiry. Specifically, the aim is to review i) on the significance of questions in inquiry ii) the key findings of student-question-based inquiry, iii) the practices, and iv) the teachers' and the students' roles in it. Methodology: This systematic review was carried out by using deductive content analysis (Elo & Kyngäs, 2007). The database research resulted in 570 articles, and after excluding non-relevant articles, 30 articles remained. As the final step of the analysis, a model, student-question-based inquiry (SQBI), was created. Finding:s This review shows that students' questions can be obtained and used in various ways, and highlights the teachers' important role in inquiry teaching already in the planning phase. The resulting SQBI-model presents how questioning can be seen both as a scientific practice and pedagogy, and questioning has a special function in driving and directing the inquiry. As an example of inquiry teaching practices before the inquiry, the questions can be formulated in the beginning of the sequence, the students and teachers can plan and carry out activities to support the following inquiry process, the content can be learned by the students or taught by the teacher, and the teacher can teach the students inquiry skills, such as question formulation. Discussion and implications: According to this review, students' questions are used in various types of inquiry activities. Besides using open inquiry, practices include using a driving question, leaving the planning for the teacher, and formulating the question as the inquiry proceeds. How much open inquiry the practice resembles, depends on how the teacher plans the process. The SQBI-model indicates that the students` questions can be used with different students, depending on what kind of support the teacher decides to give, and how the whole teaching sequence is planned. The use of this model in teacher education should especially be studied in more detail in the future.

Back to programme

(A392) WORKING MEMORY CAPACITY OF MALAYSIAN FORM FOUR SCIENCE STREAM STUDENTS

Fui Seng CHANG, *Universiti Sains Malaysia*
Mageswary KARPUDEWAN, *Universiti Sains Malaysia*
Zalina ISMAIL, *Universiti Sains Malaysia*

Abstract

Cognitive neuroscience education is perceived as a new trend in educational psychology research. In science education, there are many studies which investigate the teaching and learning processes from the neurocognitive perspective (Anderson, 1992; 1997; 2009). For instance, Alloway, Gathercole and Pickering (2006) investigated the role of working memory capacity and they suggested students with weak working memory capacities has limited capabilities to concurrently process the information. Besides that, St Clair-Thompson, Overton and Bugler (2012) studied and reported that working memory can be referred as constructive operator for problem solving and predictor for understanding as all the knowledge that we learn are stored in our working memory. This proves that working memory acts as one of the important component of memory storage to manipulate thoughts during cognitive processes. Hence, through this study attempt was made to investigate working memory capacity of Malaysian Form Four students and involved a total of 80 Form Four (16 to 17 years old) Science Stream students. Cambridge Neuropsychological Test Automated Battery (CANTAB) was used to investigate the students' working memory capacity. It is one of the automated test batteries available and most widely utilized worldwide. Spatial Working Memory (SWM) is an estimation of strategy by counting the number of times subject begins a new search with a different levels. The test begins with a number of colored square boxes being shown on the screen and the participant are required to touch the boxes by using an elimination process. The participant should find one blue 'token' in each of the boxes and drag them to fill up an empty column on the right hand side of the screen. The number of boxes will increase for each level, until it is necessary to search a total of eight boxes. The outcome analysed was the SWM between errors which indicates the numbers of times a 'token' is revisited in the box where the 'token' had already been found. SWM between errors and total errors was automatically calculated by CANTAB itself and transferred to SPSS for the analysis of mean value of the total errors. The higher scores and mean values in SWM represents poorer use of the best strategy to solve the problem and a low score equates to effective apply of the strategy. At the 4-boxes level a mean of 1.04 was obtained. This indicates that the students have used effective strategy to solve the problems and their working memory capacity is high. As such, the students have avoided committing errors during answering. When the number of boxes was increased to 8, mean value obtained was 26.93. This higher value indicates that the students have committed errors in the task and this is because of their poor working memory capacity. As such the findings of this study suggest that an effective teaching approach or working memory strategies are needed to empower students' ability to solve problems.

Back to programme

(A394) ANALYZING THE USE OF EVOLUTIONARY TREES (TREE THINKING) WITH MIDDLE SCHOOL STUDENTS

Gonzalo PEÑALOZA, *Maloka Science Center, Bogotá*
Jairo ROBLES-PIÑEROS, *Federal University of Bahía*

Abstract

The central issue of evolution, as laid out by Charles Darwin in The Origin of Species, is that living species, with their diversity in form and way of life, result of descent from common ancestors. To explain his idea, Darwin proposed the metaphor of the "tree of life." Despite the importance of this finding, reading, interpretation and comprehension of life as a succession of living beings, has not spread to a wide audience. This issue is rarely tackled in basic biological education due to its conceptual complexity and due to teachers do not know mistakes involved with its teaching and learning. Fostering skills to interpretation of evolutionary trees is a key component of all levels in biological education. "Tree thinking" skills, like constructing and evaluating hypotheses about historical patterns of descent, are necessary to understand processes that have occurred in the history of life. This paper provides an analysis of tree thinking teaching in a biology classroom. The study was developed with 35 students (18 boys, 17 girls) with an age range between 13 to 17 years old (M=15,62) of ninth degree (9°) of middle school of a Public School from Bogota (Colombia). Development of tree thinking was evaluated when the class dealt with an activity entitled "Searching for the common ancestor: building evolutionary trees", was an adaptation of a proposal of Working Group on Teaching Evolution–National Academy of Sciences (1998). This activity was selected because it combines the phylogenetic trees reading with a simple construction of them. For this, transcriptions of class recordings, field and observation notes, and data analysis documents were used. A qualitative analysis approach was used to study the students' explanations, arguments and schematic representations about the evolutionary relations between some species and their common ancestor. Starting from the analysis of diagrams that students built, of their explicative discourses and their arguments, it's possible to consider that, using the categories about levels of representational competence of Halverson and Friedrichsen (2013), the participants of this study moves between the level two (superficial use of the representation) and five (conceptual use of the representation) of representational competence. The observations and interpretations made allow asserting that the students are able to develop tree thinking and to build evolutionary relations. However, using the visual representation of evolutionary trees requires teachers to receive a kind of training that would allow them to take into account and overcome the difficulties documented in this work. The aim of this work was made an approach to the development of interpretative skills of evolutionary trees in middle school students, as this kind of research to this scholar level are scarce. On the other hand, teacher-training is a key piece to approach to issues and concepts that lead to improve the process of building and interpretation of trees based on evidence. It´s recommendable that teachers know the difficulties associated to use of visual representations, in this case, evolutionary trees.

Back to programme

(A395) UNIQUENESS OF SENIOR HIGH SCHOOL STUDENTS' SEQUENCE EXPRESSIONS OF TRIANGLE OF REPRESENTATION IN ELECTROCHEMISTRY

Chontawat MEEDEE, *Khon Kaen University*
Romklao JANTRASEE, *Khon Kaen University*

Abstract

Most of scientific contents usually deal with concrete and abstract concepts. Particularly, chemistry contents require students to interconnect among three levels of representation including macroscopic, sub-microscopic, and symbolic representation respectively in order to deeply understand. However, students have encountered learning difficulty because they need multilevel thoughts. Thus, students avoid finding out explanation for both concrete and abstract contents. Previous research findings indicated that the use of concrete educational materials can effectively help students understand abstract and difficult concepts in chemistry. This study aims at investigating how and what students express the sequence of the chemical triangle (macro, sub-micro, and symbolic representation) in learning electrochemistry. Methodology employed in this study was interpretive paradigm. Three cases of students were selected by opportunistic or emergent sampling method. Data was collected over two months by using classroom observations, interviews and students' worksheet. The Drawing of Chemical-Electrical Representations was a worksheet which was specifically designed and used for eliciting how and what students expressed their ideas of electrochemistry through drawing and writing modes. A framework used to analyse data was based on Johnstone's three representational levels. The finding showed that three patterns of students' sequence expression of triangle of representation were clearly found. First is the concrete to abstract direction (i.e., from macroscopic to sub-microscopic and symbolic representation). Second is the abstract to concrete direction (i.e., from symbolic to sub-microscopic, and to macroscopic representation). Third is the alternating direction (i.e., from macroscopic to symbolic and sub-microscopic representation). Two participants who got started at macroscopic representation first said that a scientific phenomenon from carrying out experiments was tangible and easy to observe and then record such as the change of voltmeter or the corrosion of metals. They, therefore, were able to connect these tangible phenomena to more abstractness. Interestingly, a participant who was categorized in alternative direction gave her reasoning that writing symbolic representation, for example chemical equations of a redox reaction was more abstract than sub-microscopic level - the changes and occurrences of atom or molecules. However, she found that symbol was shorter to write and it requires less details than drawing atomic phenomena, therefore linking symbolic with macroscopic representation was easier to make senses. These findings were consistent with a participant's ideas which had abstract to concrete learning style. Her interview revealed that symbolic phenomena helped her understand the mechanism of gain-loss electron in reduction and oxidation reactions in laboratory works. She could visualize in her minds and then recheck the actual occurrences from performing experiments, doing hands-on activities, and interacting with computer simulation technology. The different patterns of students' sequence expression in learning electrochemistry will be useful for a researcher and teachers to plan and design the better instructional strategies to respond and support the diverse needs of students appropriately.

Back to programme

(A398) EFFECTIVENESS OF ACTIVITY-BASED INSTRUCTION (ABI) AND INTERACTIVE LECTURE DEMONSTRATION (ILD) IN ADDRESSING MISCONCEPTIONS IN GEOMETRIC OPTICS

Sherryl PONTILLAS, *Ateneo de Manila University*
Ivan CULABA, *Ateneo de Manila University*

Abstract

As students enter their classrooms, they have their own learning styles, abilities, and qualities. They are also armed with years of rich and direct experience with different scientific phenomena in their daily life. In their attempt to generate justifications about these occurrences even before formal learning, they construct spontaneous and unstructured explanations derived from actual observations. These ideas often lead to misconceptions, which can have crucial impacts on the outcome of instruction. Hence, the quest for effective teaching methods that can successfully accommodate students' individual differences and address their misconceptions has become a worldwide concern. This study aims to compare the effectiveness of two teaching methods, Activity-based Instruction (ABI) and Interactive Lecture Demonstration (ILD), in correcting the misconceptions of the students in geometric optics. Specifically, it seeks to determine the students' level of understanding before and after the intervention was conducted and analyse if the scores statistically differ from each other. The mixed method approach was used in this study, utilizing the non-randomized pre-test post-test control design to determine the students' level of understanding before and after the intervention. On the other hand, questionnaires and interviews, with emphasis on focus group discussions (FGD) were employed to appraise students' impression on the two methods. The respondents, composed of 62 Grade 10 students, were divided into two equal groups. The ABI group used hands-on activities during their discussions while the ILD group was instructed using teacher demonstrations. The effectiveness of the two methods was determined by analyzing the pre-test and post-test scores obtained by the students. Results revealed that both methods have successfully addressed the misconceptions held by the students, as indicated by the mean gain analysis wherein both groups had statistically significant higher scores in the post-test compared to the pre-test. The scores further show that each method showed an advantage over the other in correcting certain misconceptions. In addition, the FGDs demonstrate the students' feedback regarding the methods used. Both groups agree that the interventions assisted them in verifying and understanding the concepts being discussed. Results of the interviews both on the teacher and the observer revealed the advantages and disadvantages of the methods. ABI was effective in motivating the students and promoting hands-on participation while it showed disadvantage on classroom discipline and time management. ILD, on the other hand, demonstrated strength in maintaining classroom discipline and managing the time while it was problematic in terms of motivation and providing hands-on activities. Research findings have demonstrated how misconceptions can substantially hinder effective learning. Thus, it is imperative to include accurate identification of students' misconceptions as an integral part of the teacher's lesson plan before the start of any lesson. These misconceptions should be considered in implementing the lessons and incorporated during the discussion. Assessing the students' performance should also encompass if the students have successfully corrected their misconceptions. Through this study, students

and teachers alike can expediently select the teaching method that is more suited to their needs and situation, therefore, optimizing the opportunities for maximum learning.

(A399) INVESTIGATING PRE-SERVICE SCIENCE TEACHER'S ABILITY TO NOTICE STUDENT THINKING

Sze Him LAM, *University of Cambridge*
Kam Ho CHAN, *The University of Hong Kong*

Abstract
Reforms in science education call for classroom practices that leverage student thinking as a resource for instruction. Student thinking can exist in a diversity of forms (e.g., student verbal cues, student non-verbal cues) and varying degrees of visibility when embedded in classroom interactions. Placing a substantive focus on different forms of student thinking and making sense of student thinking of various forms among the blooming and buzzing sensory data during the instruction can be challenging to teachers, especially for pre-service teachers (PSTs). While studies investigating PSTs' ability to notice (i.e., their ability to attend to and make sense of student thinking) exist (e.g., Kang & Anderson, 2015; Levin & Richards, 2011), few studies have investigated PSTs' ability to notice different forms of student thinking. The goal of this qualitative study was, hence, to explore how six PSTs attended to and made sense of various forms of student thinking captured in authentic classroom video clips of junior science classrooms. The PSTs each attended an interview in which they were asked to make observations on the video clips. The video clips were carefully chosen such that they featured with different forms of student thinking embedded in classroom interactions. The comments of the participants on the videos were content analysed with respect to the form of student thinking the participants paid attention to and how they made sense of the noticed student thinking. Findings suggested that the PSTs primarily focused on the non-verbal form of student thinking (67%). The PSTs attended to the artifacts students made (55%) and students' voting (45%). In terms of the verbal form of student thinking, the participants predominantly attended to students' explanations (69%). Seldom did they attend to the questions asked by students (6%). The way that PSTs interpreted student thinking was found to be independent of the form of student thinking. The participants mainly focused on what learning difficulty/confusion the student might have encountered (45%). Rarely did the PSTs unpack student thinking in terms of what students might mean in the context (2%), the specific scientific content of student thinking (2%), or the source of student thinking (2%). Collectively the findings point to two important conclusions: (a) different forms of student thinking might owe varying degrees of visibility to the PSTs and (b) making sense of what students might mean or the specific content of student thinking might remain an obstacle to the PSTs, regardless of the form of student thinking they have attended to. The findings highlight a need to incorporate targeted noticing activities such as tasking PSTs to notice specific forms of student thinking that they are not sensitised to and providing scaffolds to direct PSTs to unpack the meaning of student thinking.

Back to programme

(A400) EXPLORING THAI STUDENTS' SOCIAL EQUITY PERSPECTIVE THROUGH SOCIOSCIENTIFIC ISSUES.

Chanathip JANSONG, *Kasetsart University*
Sasithep PITIPORNTAPIN, *Kasetsart University*
Pramote CHAUMNANPUEN, *Kasetsart University*

Abstract
Nowadays, social equity has become one of Thailand's social development policies. The government encourages Thai's people in society to live in harmony and accept each other differences such as gender, races and economic status. There are a lot of issues that cause of conflicts about social equity whether it is human equity, the rights and freedom to live as a human being in society at present. Socioscientific issue is one of conflicts related to social equality particularly to human being's issues. This research used socioscientific issues (ssi) in science classroom to encourage students expressing their views on social equity through classroom discussions. This research aimed to explore students' view of social equity via ssi-based teaching. Three issues were used in this research including giving vaccine for immigrant in Thailand's boundary, Living with HIV's people, Prohibition LGBT in blood donation in Thailand. The participants are grade 10th students (n=48) studied general biology and students had learned basic concepts in immune system and disorder prior to the beginning of this study. Using ssi-based teaching following Eilks (2010) consist of five steps introduction, clarifying with science knowledge, making relationship between science knowledge and issues, role play activity and reflection. Videotaped discussion and written worksheets were the instrument for collecting data, qualitative analysis of the videotaped discussions was based on part-to-whole inductive approach (Erickson, 2006) and content analysis for written worksheets. Findings showed that their personal social equity perspective involved "human equity", "human rights", "freedom" and "gender equity." Example of student's social equity view on giving vaccination for Thai's immigrants issue is "I think we should give vaccine for them because we are the same human, we have to focus on their health first more than focus on their race. It's an ordinary right that they should to receive as human being." Opinion in living with HIV's people issue is "I agree to live with someone who is HIV positive, because nowadays, we have improved HIV medicine. They should have the same rights and freedoms as other people in society." And their view about Prohibition LGBT in blood donation is "Personally, I think that every gender is equal. No matter which sex is likely to be infected with HIV, it depends on their habits, whether male, female or LGBT, everyone can be infected so we shouldn't ban LGBT in blood donation." From these examples indicated that Thai's students in this class have social equity view as two dimension are human equity in rights, living and gender equity in right, living. These perspectives are rooted in the study, living with the social instillation. Applying social equity discussion in science learning will help students see other's perspectives and widen their view. Moreover, it will also make science teaching as a part of social development and a view on the lives of students, in addition to using the knowledge to solve everyday problems. Further study should bring other issue in science classroom in order to engage students' views on social equity in multiple dimensions.

Back to programme

(A410) AN ANALYSIS OF TEACHING METHODS IN SCIENCE LESSONS: BASED ON THE RESULTS OF NATIONAL ASSESSMENT OF ACADEMIC ABILITY IN JAPAN

Takuya MATSUURA, *Hiroshima University*
Hiroyoshi KINOSHITA, *Hiroshima University*

Abstract
Problem: Japanese Ministry of Education, Culture, Sports, Science and Technology (MEXT) annually conduct ' the National Assessment of Academic Ability' for 6th and 9th grade students since 2007. At first, this assessment focused on only Japanese language and arithmetic/mathematics, but now it additionally focuses on science every three years from 2012. This assessment treat not only the students' academic ability but also teachers'/students' consciousness about teaching or learning. For example, National Institute for Educational Policy Research (NIER, 2015) reported the relationship between the science score and learning environment, the schools that conduct science lessons in laboratory many times indicated the better science ability than less use schools. But teachers' questionnaire cannot treat details of science teaching because it includes very wide topics about teaching. Goal/Design: The purpose of this research is to clarify the relationship between the science score and teaching methods in science lessons at elementary and junior high school. We conducted additional new questionnaire (16-items, 5-Likert scale) research about teaching methods to science teachers with random sampling at school level. This questionnaire was administered to 277 elementary school teachers and 218 junior high school science teachers who taught science to 6th graders or 9th graders one year ago in August 2016. Based on the results of this questionnaire and school average of science IRT score, we analyzed the relationship between the science score and teaching methods in science lessons. Analysis and Findings: We classified teachers into four school groups according to the science IRT score, and that groups were used to analyze the results of questionnaire and comparing the percentage of positive answers for each item. For statistical comparison with each school level about the percentage of positive answers, we used Bayesian method by R and RStan with HMC method. Findings of this analysis are below: Feature of High level schools (teachers) (elementary) Q03. Students need to think about control variable Q06. How to do/write the discussion Q07. Students need to explain their own idea Q10. Interpretation from Table and Graph Q11. Do a review of previous knowledge/formula Q15. Using the problem solving approach (junior high) Q01. Students need to understand the purpose of experiment Q02. Making up how to show the scientific phenomenon Q04. How to write Table and Graph Q05. How to write/do the results and discussion Q07. Students need to explain their own idea Q15. Using the problem solving approach Discussion: The common results of this research indicate that 'using the problem solving approach with concrete instruction' and 'the situation that students need to explain their own idea' are helpful to develop students' scientific ability. Of course, there are many factors to develop the students' scientific ability that we don't treat in this research, therefore we need to study from multiple aspects.

Back to programme

(A412) MISCONCEPTIONS OF DIFFUSION AND OSMOSIS IN BIOLOGY UNDERGRADUATES

Jessica TAN, *National Institute of Education, Nanyang Technological University, Singapore*
Shit Fun CHEW, *National Institute of Education, Nanyang Technological University, Singapore*

Abstract
Diffusion and osmosis are two key fundamental processes in Biology that are normally taught in basic physiology modules in the first year of university. As reported previously, the mastery of these two processes is difficult to achieve in students of various education levels. However, the knowledge of these two processes is necessary for Biology undergraduates to understand important life processes like how the organ systems function in organisms that are covered in Human/Animal and Plant Physiology courses. These courses are usually taught in their subsequent years in University education. Therefore, it is imperative that undergraduates are equipped with the correct concepts of diffusion and osmosis before they proceed to learn about topics that involve the application of these two processes. Common misconceptions of diffusion and osmosis are known to persist in students from various education levels. Hence, the objective of this study was to investigate if there exist a correlation between the number of misconceptions Biology undergraduates have regarding diffusion and osmosis and the number of years of their university education. An 18-item Osmosis and Diffusion Conceptual Assessment (ODCA) was distributed to 45 Biology undergraduates studying at the National Institute of Education (NIE) in Singapore. The 18-item ODCA was grouped into three categories: (i) diffusion, (ii) osmosis, and (iii) diffusion and osmosis before further analysis of the undergraduates' misconceptions was performed. The ODCA was developed as a two-tiered, multiple-choice test with the first part of each question assessing the fundamental concept from one of the three categories mentioned above while the second part of each question assessed the understanding of that particular concept. During the analysis, two questions from ODCA were excluded as these questions did not fit into any of the defined categories mentioned above. The ODCA was slightly modified to further assess the undergraduates' understanding of the two processes by asking them if they agreed with the phrasing of the suggested answers in part two of the question for the first three items. Results obtained showed that on average, the percentage of undergraduates from Year 1, 2, and 3 who had both parts of each question correct were: 74.3%, 89.5%, and 84.1%, respectively. Hence, there was a general trend that as undergraduates progressed to higher levels in their undergraduate education, they were more likely to have fewer misconceptions regarding the two processes. The underlying reason for this trend could be because of the compulsory Animal and Plant Physiology courses that they have to attend in their third year of University education in NIE. Interestingly, the result obtained from the Year 4 cohort was 63.4%. This could be because the year 4 cohort has a mixed group of students (Biology undergraduates from Year 1 and Diploma of Education students that cross over to the BSc programme). With the information on the misconceptions of diffusion and osmosis in Biology undergraduates obtained in this study, new and more effective pedagogies could be designed to address them at the secondary and tertiary levels.

Back to programme

(A413) PROVIDING LANGUAGE SUPPORT TO HELP PRIMARY SIX STUDENTS WRITE BETTER EXPLANATIONS IN SCIENCE

Alison TAN, *Ministry of Education, Singapore*
Jonathan LO, *Endeavour Primary School*
Cai Ying LOH, *Endeavour Primary School*

Abstract

This action research study heeds the call of scholars who recognize the need for literacy instruction in the science classroom (Gibbons, 2009; McConachie & Petrosky, 2010; Moje, 2008; Seah, 2016). Viewed through the lens of disciplinary literacy, learning science entails more than just the acquisition of content knowledge. In order to be successful, students must also master the specific ways of reading, writing, thinking, talking and doing that are unique to science, all of which can be challenging for the uninitiated. One implication for science teachers is that they need to provide support not only for conceptual development, but also the linguistic demands of the subject. This study focuses on two science teachers' effort to help their students write better explanations in science via the provision of language scaffolds. Specifically, it sought to answer the question, What are the effects of providing language support on students' written answers for Science questions? A total of seventy students from two Primary Six classes participated in the study. The teachers had observed that their students, even the high progress ones, struggled to write accurate answers to open-ended questions, despite displaying an understanding of the science concepts involved. The teachers collaborated with a consultant from the English Language Institute of Singapore to infuse language scaffolding into a five-lesson unit on Food Chains and Food Webs. Informed by the principles of making thinking visible (Richhart, Church, & Morrison, 2011), the gradual release of responsibility model (Fisher and Frey, 2008), and the cognitive apprenticeship approach (Collins, Brown, & Holum, 1991), the scaffolding strategies included the explicit instruction of content vocabulary, the provision of sentence stems and writing frames, teacher modelling via think alouds (I do), teacher-guided writing (we do), collaborative writing (you do together) and individual practice. The students were given the same question to answer at the start and the end of the unit so that the teachers might assess their learning. Different questions were used during the lessons. All lessons were videotaped. Content analysis was performed on all written answers for clarity and precision. Results revealed that a majority of the students showed improvement in their writing while a small group of students continued to produce inaccurate or imprecise answers. A closer analysis of their answers and interviews with the students revealed three reasons for the weak answers: students who chose not to use the prescribed vocabulary or writing frame, students who expressed difficulty in reading the food web and students who were confused about the scientific concepts. Based on the findings, the teachers were able to design follow-up lessons that addressed the learning gaps. Both teachers are convinced by the findings of this study about the benefits of infusing language scaffolding into science lessons in order to improve student writing. As a result, they plan to share and implement the strategies across the whole science department in their school the following year. This study demonstrates the efficacy of well-designed language support strategies to improve student writing in science.

Back to programme

(A415) INVESTIGATING FORMATIVE ASSESSMENT PRACTICES IN SCIENCE CLASSROOMS

Hye-Eun CHU, *Macquarie University*
Kim Chwee Daniel TAN, *National Institute of Education, Nanyang Technological UniversitySingapore*

Abstract
The aim of this study to investigate teachers' formative assessment practices in science classroom. This research involved developing a video analysis coding scheme and investigating formative assessment practices in Secondary 3 science classrooms where students learn thermal physics concepts. This study involved five teachers from three schools teaching year 9 science in Singapore. Two of the teachers were graduated from teacher training with two years teaching experience in Science. Two of the teachers and another one have more than ten years and five years teaching experience respectively. The average class size was 40 students per class. The students were ranged from low to average ability. Three out of five of the teachers participated in formative assessment workshop before the research was carried out. Data source is videotapes of science lessons. Teachers set up the video camera at the back of the classroom to capture their own teaching. It was directed at the teacher and the white board. Total of 15 video-clips of the lessons were observed which comprised a total of about 15 hours. All teachers provided 2 videos at least except John (1 video). Six out of 15 video-clips were selected based on the topic and teaching approach including formative assessment. The lessons covered a range of topics included in the science syllabus. These included heat conduction, heat capacity, latent heat, radiation and melting process. Teaching resources (example: lecture slide, video, demonstration etc…) captured in the videotape and verbal data from the transcripts were served as primary sources of data. Data were analysed with a focus on teaching resources, teacher elicitation and student response and types of teacher feedback based on on-going formative assessment in the classroom. Classroom talk between teacher and students were transcribed verbatim by Transana software. Coding scheme was implemented to the science video data. We developed a framework for constructing individual codes. Our coding mainly focusing on three sections: 1) teacher elicited questions and students' responses, 2) student-elicited questions and students'/teacher's responses (with a side note of teaching resources) and, 3) types of tasks supportive of formative assessment and feedback (individual feedback, group feedback, and whole classroom feedback). We watched the videotaped lessons to confirm the codes and to provide additional information for the more detailed codes if necessary following the coding development cycle. Findings show that the teachers used open/guided questions but the types of accepted students' explanations/responses varied. These include well-elaborated answers, short answers, or silence with active thinking. Five of the six teachers provided direct feedback on students' responses instead of encouraging students to construct their own explanations. One teacher was unable to maintain dynamic classroom interactions because 3-4 questions were continuously asked each time. This teacher also failed to identify absentees and missed students' appropriate responses that could have been used for continual conceptual development through further questioning. No peer assessment and students' self-assessment was observed and teachers' feedback appeared as a summary of teaching. Further analysis will be conducted to quantify the qualitative video analysis using Videograph software.

Back to programme

(A417) HOW DO I DEVELOP 5-GRADE STUDENTS' COLLABORATIVE SKILLS USING SCIENCE, TECHNOLOGY, ENGINEERING AND MATHEMATICS (STEM) EDUCATION?: CLASSROOM ACTION RESEARCH

Panuvit CHANTARA, *Kasetsart University*
Sasithep PITIPORNTAPIN, *Kasetsart University*

Abstract

Nowadays, Thailand's education policy have been changing to "Thailand 4.0" which is aiming to the future Thai-innovation-centre. the government encourages Thai's people to become more productive and to create more innovations. There are a lot of students' skills must have been developed including collaboration skills in 21st-century skills. Thus Science, Technology, Engineering, and Mathematics (STEM) education is the method to reach their goal. The purposes of this study were to study the characteristics of Science, Technology, Engineering and Mathematics (STEM) education to develop the 5-grade students' collaboration skills, and development of 5-grade students' collaboration skills. 6-STEM education procedures were brought to observe the classroom related to the topics of force, sound and hearing. Each students' groups learned through the 5-inquiry methods with collaborative activities, such as Think-Pair-Share, Jigsaw, and Expert group, including STEM activities in an elaboration of inquiry. For the data acquisition, the students' learning journals, informal interviews, teaching logs and video, and collaboration assessment form were obtained from 31 5-grade students during the second semester of 2017 academic year from the middle-size-elementary school in Bangkok province, from the poor area. This study employed the qualitative data which are frequency, relative gain score, means, and percentages. Moreover, for analysing quantitative data, the researcher used a content analysis for categorising students' learning journals and informal interviews. The results showed that most of the students' collaboration skills were increased after learning with STEM education. Their collaboration skills in the first and the second phase the relative gain score were improved by 41.59% and 36.81% respectively. Thus, their mean score was improved from 2.76 to 2.86 and 2.91 respectively. 26 students (83.87%) developed their collaboration skills to the best level. 2 students (6.45%) developed their collaboration skills to a good level. However, 1 student (3.23%) did not develop the collaboration skills, mainly influenced by unfamiliar argumentation. Moreover, the characteristic of STEM education for development of students' collaboration skills included; 1) using inquiry approach with collaborative activities to elaborate with STEM; 2) the students' activity paper must be included with engineering process to better understanding how to design effectively; 3) using technology, such as ClassDojo, to create a team is making them more interesting and having more collaborative; 4) telling the students' with task features are more interested and having more responsibility; 5) giving students opportunities to assess themselves and their friends' collaborative. For further study, the STEM situation should be considered based on the daily life issue or social related to students' interests and experiences to promote the define-problem step. With a better understanding derived from the further study, science teachers and educators might modify their teaching practices with STEM education process with other learning approach or other methods to develop students' collaboration skills by improving STEM education process.

Back to programme

(A420) HOW SCIENCE TEXTBOOKS COULD AFFECT STUDENTS LEARNING IN INFORMAL LEARNING ENVIRONMENTS

Fatema ALAMOURI, *University of Reading*

Abstract

"Could something called a science book touch us in a way that helps us to perceive the world differently, with new eyes and ears and hands?" (Saul, 2000, p. 117).

Most educators agree that textbooks are the most prevalent instructional materials used in schools by teachers and pupils. Many literature sources describe textbooks as the major key classroom teaching aid in schools. According to many studies, textbooks have a strong influence on the learning sequence and teaching methods adopted by teachers, while also impacting significantly on students' learning experiences. Directly or indirectly, textbooks influence science teachers in terms of instruction planning, learning activities, homework, and even tests and assessment. Likewise, science textbooks play a pivotal role in creating and shaping the students' understanding, attitudes, and perspective regarding science issues, the relationship between science, their life and the universe. However, recent science textbooks have limited impact on integrating pupils with science in the real world. The literature for this study explained in-depth the concept of informal learning, the effect of integrating formal science learning and informal learning environments, the role of textbooks informal science learning, and how informal learning environments could be integrated into science textbooks. Therefore, this study was conducted to investigate the extent to which informal learning issues are presented in science textbooks in Omani schools, and how science textbooks used currently in Oman encourage teachers and students to use informal learning environments. For this purpose, a sample of textbooks and science teacher guides (grade 6,9,10) have been analyzed. An inductive qualitative analysis approach has been taken to determine how informal learning environments and informal learning activities are presented in the chosen science textbooks and teacher guides.

The finding of this study summarises the basic themes drawn from students' textbook and teacher guides through which the curriculum refers to informal learning, either directly or indirectly. The results of this study revealed that the analyzed textbooks did not link sufficiently the student to the informal learning environment. Moreover, it demonstrated that the learning units included in the study sample reflected unbalanced inclusion for informal learning themes. Therefore, the study made important recommendations for curriculum developers regarding the importance of including informal learning environments in curricular materials. It also highlighted how science textbooks can be written in a way that promotes different aspects of scientific literacy and helps students create a real and lasting connection between what they learn in school and real life outside the school walls.

Back to programme

(A422) STUDENTS' CONCEPTIONS RELATED TO BONDING IN IONIC COMPOUNDS: AN INTERVENTIONAL STUDY USING MULTIPLE REPRESENTATIONS TO EXPLORE AND RECONSTRUCT STUDENTS' IDEAS

Sitalakshmi RAMAMURTHI, *University of Delhi*

Abstract

Studies by Butts and Smith (1987), Taber (1997), and Coll and Treagust (2003) have reported the difficulties faced by students in understanding the models of ionic bonding, and brought out students' alternative conceptions related to structure and properties of ionic substances. The difficulties have been attributed to the abstract nature of bonding concepts and the complexity of models (Unal, Calik, Ayas and Coll, 2006), to the way bonding is taught and its representations in textbooks (Bergqvist et al., 2013) . Researchers Taber and Coll (2002), Levy Nuham et al. (2010) have laid an emphasis on teaching bonds as electrostatic forces of attraction. Unal et al. (2006) have also brought out the need to focus on alternate strategies of teaching to overcome students' alternative conceptions of bonding. This paper reports a study in which an attempt was made by the author (researcher) to facilitate students' understanding of bonding concepts through intervention sessions incorporating use of multiple external representations, like static pictures, dynamic visualizations, and student generated atomic level diagrams. Use of multiple external representations (MER's) to communicate scientific ideas and its benefits in science learning have been documented in literature. (Corrandi et al., 2014). Wu and Puntambekar (2012) have emphasised the active engagement of students during use of MER's and also pointed out the need for further studies on the effectiveness of MER's by embedding MER's in different teaching approaches. In the current study, conceptions of bonding of 35 students of Grade 11 of an urban private school in Delhi, were determined through an open ended questionnaire, followed by in depth conceptual interviews of students who agreed to be questioned further. Intervention sessions were then designed and implemented, based on constructivist principles. The teaching learning process in the intervention sessions incorporated multiple external representations and had the following steps: elicitation of students' constructs, restructuring of ideas (small group discussions around MER's), application of new ideas and learner's reflection on the learning taking place. Students' change in conceptions was studied through a pre-test, post-test, delayed post-test design. The data sources were students' written responses, molecular level student generated diagrams, responses to semi-structured interviews, students' reflective journals, and researcher's field notes. This paper presents a qualitative analysis of a part of the study: students' conceptions about ionic bonding and melting of ionic compounds. The change in conceptions of ten individual learners as 'cases' has been analysed qualitatively, categorized and coded , and inferences drawn to understand the pathway of conceptual development. It was found that teaching learning sessions facilitated students' understanding of 'ionic bond' beyond 'the octet' and 'electron transfer' to an understanding of the ionic lattice in terms of attractions and repulsions. However, there were a few instances where the alternative conceptions resurfaced in the delayed post-test. The paper also discusses the challenges of using constructivist pedagogy and multiple external representations in the prevailing classroom situations in India at the senior secondary level, and the implications of the study for classroom practice.

Back to programme

(A424) EVALUATING PUPIL PERCEPTION IN THE USE OF TECHNOLOGY IN A PRIMARY SCIENCE CLASSROOM

Grace QUEK, *Catholic High School (Primary)*

Abstract

The use of technology in Science was designed to incorporate the teaching and learning of 21st century competencies such as thinking and communication skills. This paper aims to explore how the use of technology better engage primary six pupils (12-years-old) and promote collaborative learning in a primary Science classroom. Research has shown that there is greater pupil engagement when ICT tools are used in lessons (Coll, Rochera & Colomina, 2010). Tapping on the use of technology, a unit plan on Adaptations was created in Google site to increase pupils' engagement level through the provision of opportunities for collaboration. Video links and slides were included to guide the pupils. Pupils were grouped according to their ability in doing the tasks assigned. Such differentiation allows teachers to focus on essential skills in each content area and be responsive to individual differences (Tomlinson, C., 1999). Each group explored the various links and pupils published their work and share with the peers, to view and comment their discussions. Such collaborative tools allow them to learn from one another and from the teacher (Chai, C.S, 2011). The Constructivist-Oriented Learning Environment (COLES) Questionnaire was used to evaluate pupil perception in the learning of Science. The survey looked into three areas - Pupil Involvement, Pupil Task Orientation and Pupil's Enjoyment of lesson. Qualitative and quantitative data and feedback indicated that pupils' learning became more enriched and meaningful. They enjoyed collaborative learning and harnessing the affordance of technology, and had the opportunities to work individually and in teams. The scale mean of 3.8 for pupil involvement indicated that pupil had opportunities to contribute to group discussions. For task orientation, the scale mean was 3.4, and pupils gave feedback that more time should be given for discussion and completion of task. The scale mean of 4.3 for pupil's enjoyment of lesson showed that pupils' engagement increased with the use of technology and collaborative learning had also triggered their interest in the learning. The use of online platform and collaborative tools such as the Google Site allows the lesson to be more structured and organised. Pupils do not need to refer to other hard copy resources. Shared Google Document allows the teacher and pupils to observe the groups' work real-time. Pupils can provide feedback for other groups as they observe their work, allowing peer support learning. There is greater pupil engagement when ICT tools are used in lessons. The challenges faced were the limited network connections and log-in issues. The presence of the ICT executive provided the technical support and allowed the teacher to focus on the lesson delivery. Another limitation faced in this study was the affordability of one-to-one computing so that every pupil could contribute to the discussion. Hence with the appropriate hardware and software support, the use of technology in relevant Science topics will be an effective pedagogical approach to increase pupils' engagement and depth of learning in primary school pupils.

Back to programme

(P185) ASSESSMENT LITERACY OF SCIENCE TEACHERS ACROSS LEVELS

Rizalina ANDAMO, *Philippine Normal University*

Abstract
Assessment plays an important role in teaching and learning process as it benefits both the teachers and students in number of ways. It can be considered as a significant determinant of what, when and how students learn. It is also a powerful tool in enhancing classroom instructions. In 1990, the American Federation of Teachers, the National Council on Measurement in Education, and the National Education Association have constructed the standards for teacher competence in educational assessment of students based on the concept that assessment is an integral part of instruction and the effective instruction cannot take place without good assessment of students. The seven standards assert that teachers should be skilled in (1) choosing assessment methods appropriate for instructional decisions; (2) developing assessment methods appropriate for instructional decisions; (3) administering, scoring and interpreting the results of both externally-produced and teacher-produced assessment methods; (4) using assessment result when making decisions about individual students, planning teaching, developing curriculum and school improvement; (5) developing valid pupil grading procedures which use pupil assessments; (6) communicating assessment results to students, parents, other lay audiences and other educators and; (7) recognizing unethical, illegal, and otherwise inappropriate assessment methods and uses of assessment information. To evaluate the literacy on student assessment, 30 science teachers who were teaching in the elementary, secondary, and tertiary levels were purposively sampled and surveyed using the 35-item multiple choice format of a Classroom Assessment Literacy Inventory (CALI) which was designed parallel to the Standards for Teacher Competence in the Educational Assessment of Students. The responses of the teachers were coded in two scoring schemes; binary and partial-credit using the Structure of Observed Learning Outcomes (SOLO) Framework. To determine in which area were the science teachers good in and where they needed professional support, and to explore their overall assessment literacy and its relation to their gender, educational attainment, and years of teaching experience, mean, frequency, standard deviation, t-test, and one-way analysis of variance (ANOVA) were utilized. Results revealed that Science teachers have an overall average level ($M=1.47$) of assessment literacy, with low level ($M=0.58$) for Competency No. 6. Furthermore, results showed that there is no significant difference between scores of male and female using the binary scoring and partial scoring respectively ($t=-0.223$, $p=0.826$) ($t=-0.083$, $p=0.935$); no significant difference between the science teachers' educational attainment and assessment literacy scores for three conditions [$F(2,27)=0.346$, $p=0.711$], [$F(2,27)=0.565$, $p=0.575$]; and no significant difference between teaching experience and assessment literacy scores [$F(4,25)=0.789$, $p=0.543$], [$F(4,25)=0.465$, $p=0.761$]. The study recommends that Science teachers are given well-developed programs that will increase their assessment literacy, especially in the area where they will develop or improve their skill in communicating assessment results to students, parents, other lay audiences, and other educators. Conduct of similar studies is also recommended, involving a larger number of science teachers and/or teachers from other areas of

specialization to strengthen validity of results and contribute to improving assessment literacy of teachers across fields.

Back to programme

(P189) DOES SEEING MEAN LEARNING? A QUALITATIVE STUDY OF MULTIMEDIA DESIGN (MMD) PRINCIPLES AND MOLECULAR REPRESENTATION USING EYE TRACKING AND VERBAL PROTOCOLS

Poh Nguk LAU, *Temasek Polytechnic & Columbia University*

Abstract

The ability to integrate information across different representational forms is a very critical skill in Chemistry. Most often than not, Chemistry students are required to grasp concepts that has to be understood from the macroscopic, symbolic and molecular realm, forming what is known as the “triplet” nature of the subject (Johnstone, 1982). Chemistry educators have a burgeoning choice of digital learning resources to assist students in multi-modal integration. However, a critical question remains very much unanswered today in the field of chemical education research. What do learners attend to when they view these materials, are they looking at the intended stimuli and how are they processing the information to learn the required concept? To answer these questions, eye tracking technology has been deployed in education research in recent years, complemented with cued retrospective replay of eye movements. In this small pilot study, the intent is to ask if watching an animation movie that shows the unfolding of molecular events might elevate multi-modal representation competency. This study examined how visual attention was allocated in the presence or absence of MMD features using visual or narrated cues (Mayer, 2008), while watching an animation video on a redox reaction. The reaction involving silver nitrate and copper was presented at two levels, with a video showing the experimental changes and another at the molecular level. Five participants with Chemistry background from Columbia University participated in this study. Eye movements were recorded in the initial view of the experimental and molecular video. Verbal comments were collected in the retrospective replay of gaze points on the molecular clip with an interview protocol. Participants also drew molecular sketches to imagine how the molecules and ions were interacting, and were asked to revise their sketches after the gaze plot replay. Preliminary analysis on the molecular animation without statistical analysis indicated that participants tended to notice faster a feature with appropriate visual or narrated cues, gaze longer and more often at it. Participants’ verbal comments also corroborated the eye measurements on two aspects, the utility of the MMD elements and the cognitive processes while focusing on a particular stimuli. Participants recalled that they gazed intently at cued objects to integrate prior off-screen or on-screen knowledge. Water molecules, though not directly implicated in the electron exchange, were of interest because of the role they play in the color change. Verbal articulation of water molecules did not appear to be a direct outcome of frequent or intense gazing, and only one participant included water molecules in the sketch after the replay. However, no participants mentioned the critical role of water molecules on color change. Thus, visual perception or verbal articulation of conceptually critical features may not firstly, translate to competency in molecular representation and secondly, to multi-modal representational ability. While the small sample size and other design issues limited the generalizability of results, the study showed the usefulness of eye tracking methods in studying MMD principles and proposed other research questions for follow-up work.

Back to programme

(P191) AN ATTEMPT TO THEORIZE THE LESSON STUDY: FOCUSING ON TEACHERS' KNOWLEDGE

Tetsuo ISOZAKI, *Hiroshima University*
Takako ISOZAKI, *The University of Toyama*

Abstract
Science teachers' laboratory practice, classroom lectures, and Lesson Study are the basis for systematic improvement of teaching and learning within a cultural context (National Center for Education Statistics 2006). Such practical methods are not based on theory, but rather on the traditional wisdom and expertise of practitioners. The integration of research perspectives into teachers' practice is necessary to unite research and practice. An understanding of the aspects of knowledge that teachers interpret and transform for science lessons will help bridge the gap between research and practice. Lesson Study is an important means for improving teaching and learning (Isozaki 2015); however, there have been only a few attempts to theorize it. As an aim of this research, in order to theorize Lesson Study, the authors have employed theories on teacher knowledge and the didactic transposition theory to connect research and practice. Lesson Study is composed of three parts: preparation, the research lesson, and the reflective meeting. According to a research conducted on Lesson Study among lower secondary school science teachers (N=177) in Hiroshima in 2016, 50.8 percent of the teachers responded that kyouzai-kenkyū, which means researching and developing teaching materials, best facilitated their professional development. This step, along with preparing lesson plans, make up the main part of the reparation phase; this phase requires teachers to identify the lesson's implicit and explicit scientific and didactic values. Shulman (1987) categorized the concept of a knowledge base into seven types of knowledge, one of which is Pedagogical Content Knowledge (PCK). PCK can play an important role in the Lesson Study preparation phase (Isozaki 2015), because teachers transform their subject content knowledge in order for it to become teachable and learnable. Chevallard (1989, 1999) calls the process of adapting knowledge into something teachable and learnable the "didactic transposition of knowledge," and the meaning of knowledge depends on the institution or group; as Tiberghien and Sensevy (2015) pointed out, didactic transposition is a theoretical tool for analyzing the curriculum and implementing teaching practices. The didactic process includes three steps: (1) from scholarly knowledge to knowledge to be taught, (2) from knowledge to be taught to taught knowledge, and (3) from taught knowledge to learned, available knowledge (Bosch and Gascón 2006). Science teachers are responsible for these types of knowledge, as they determine how to teach in a manner suited to their students, and they carefully focus on and take part in what Winsløw (2007) described as "internal didactic transposition": from knowledge to be taught to taught knowledge, and from taught knowledge to learnt knowledge. The research and development of teaching materials, along with making lesson plans, encapsulate these processes of internal didactic transposition. While Lesson Study is important for developing a teacher's professional knowledge, researchers can use theories on teacher knowledge and didactic transposition to analyze the transformation of professional knowledge of novice and experienced teachers in Lesson Study to provide them with feedback (for example, what is transposed/transformed and why) and help teachers draw on their knowledge to decide what and how to teach.

Back to programme

(P200) IS THE TEACHING APPROACH OF PEER-REVIEW AN EFFECTIVE TOOL FOR IMPROVING LABORATORY REPORT-WRITING SKILLS FOR STAGE2 BIOMEDICAL SCIENCE STUDENTS AT NEWCASTLE UNIVERSITY MEDICINE MALAYSIA (NUMED)?

Pamela Anne KNIGHT, *Newcastle University Medicine Malaysia*

Abstract

Research skills such as scientific communication, analytical and critical thinking, teamwork and problem-solving have long been identified as key employability skills for bioscience graduates, and are increasingly perceived to be as important as technical and knowledge skills routinely incorporated into undergraduate science programmes. To this end, the BSc(Hons) Biomedical Sciences (BMS)(2+1) programme at NUMed Malaysia, analogous to the BMS programme in Newcastle UK and now in its' fifth year, incorporates a range of Practical Skills modules which integrate "employability" skills with more traditional laboratory practices. This project, focussing on the Stage2 Practical Skills module "Practical and Presentation Skills in Biomedical Sciences" (BMN2013), was generated in response to assessment performance and student concerns about research career preparation collected during a pilot questionnaire. The BMN2013 module aims to develop skills needed for BMS students in their final year (Stage3) and a future research career. A major component of this module is writing a summative practical laboratory report. Laboratory report writing is not only a key employability skill but also a major component of BMS students' Stage3 research project assessment and final grade. Mean assessment results of NUMed BMS students undertaking Stage3 research projects were found to be significantly less than the equivalent Newcastle UK BMS cohort in a number of areas, including laboratory report writing (5% difference in means ($P \leq 0.05$, two-sample T-Test)). In order to address this issue, new seminars, held in the NUMed IT cluster, were incorporated into module BMN2013 using small-group work and peer-assessment to both examine and grade example laboratory reports, and for students to gain feedback on their own laboratory report writing skills. Peer-review and peer-assessment have been frequently highlighted in the literature as beneficial to student learning, and are increasingly being used in science degree programmes. Evaluation of the first round of this teaching intervention (2016-17) was predominantly through online anonymised questionnaires released to Stage2 BMN2013 students at the start and end of the module, in conjunction with observations of student engagement with the sessions, discussion with colleagues and evaluation of assessment performance. Comparisons between both questionnaires indicated that while the seminars were engaged with and perceived as being the "most helpful" session by 20% respondees, there was no significant increase in student confidence in laboratory report writing skills as a result of completing this module. Furthermore, most respondees conveyed a "lack of confidence" in peer-assessment, which is echoed in the literature concerning Asian student concepts of this assessment approach. A second issue, highlighted by evaluation of BMN2013 assessment performance, indicated individual analytical skills would benefit from further development. These findings have clear implications for curriculum development as it is proposed to increase the use of peer-assessment in the BMS programme in the future, in addition to an increasing emphasis on student data-handling skills. The BMN2013 teaching interventions are being further modified to address these issues in a second, current

research cycle of this project (2017-18). The implications of these findings for future development of the BMS programme will be discussed.

Back to programme

(P233) RE-CONCEPTUALIZING SCIENTIFIC LITERACY IN THE CONTEXT OF URBAN FARMING

Gyeong Mi GI, *Seoul National University*
Sonya N MARTIN, *Seoul National University*
Saerom AHN, *Seoul National University*

Abstract
Over the last decade, there has been some debate concerning the meaning of science literacy. Traditional science literacy focuses on the acquisition of scientific knowledge as a main goal. Responses to the call for science for all has shifted perspective from traditional notions of scientific literacy towards more expanded notions that involve the utilization of knowledge in everyday life to address social issues and support decision making processes. To support the development of a more expanded notion of scientific literacy, researchers have advocated for moving away from school-based teaching and learning environments to more informal science learning settings and for broaden the object to include public and citizen. In this study, we explore the ways in which citizen participation in urban farming contributes to the development of science literacy. The practice of urban farming, also known as urban agriculture or urban gardening, involves the cultivation, producing and distribution of food grown by individuals in a densely populated area. Since 2012, more than 1 million people have participated in urban farming in Seoul, South Korea. This study examines participants' development of scientific literacy regarding plant cultivation and social engagement in a communal farming environment in an urban farm in Seoul. We explored how participation in a self-guided informal learning environment supported participants to develop their science literacy. Specifically, we explore the following: How does participation in an urban farming provide opportunities for informal learning? How does participation contribute to scientific literacy and which experiences support knowledge production and acquisition? To answer these questions, we explore how participants make decisions in relation to social issues related to the activity of urban farming or everyday life, including responding to environmental stresses (such as drought, flooding, and pestilence) and becoming aware of issues related to natural or traditional farming practices. We also explore how participants learned to negotiate relationships with neighbouring participants and the governmental agencies with development of scientific literacy. The study is based on a triangulation of data-collection techniques, consisting of document review, semi-structured interview, and participatory observation. Findings from this study offers insight into the kinds of scientific knowledge and experience that participants gain from their engagement in urban farming and reveals some of the challenges and benefits associated with urban farming as an informal learning environment and scientific literacy practices that can support participants to make informed decisions about social issues related to agriculture and the environment. Through a re-conceptualized scientific literacy lens, our findings explain and give shape to an expanded understanding of scientific literacy in informal learning environments. Implications for concrete development of informal science programs that support participants to access socio-ecological science issues and appropriate the kinds of socially expanded scientific knowledge to successfully cultivate their crops is discussed and questions are raised about the need for urban farm programs to provide more structure and support

to participants to help them better negotiate social relationships with fellow participants and to expand participants' sense of ownership and responsibility for the collective success of the garden community.

Back to programme

(P243) EFFECTS OF TEACHING PRACTICES ON STUDENTS' ACADEMIC PERFORMANCE IN SCIENCE

Marcelino IBANEZ, *Division of Masbate, Department of Education, Philippines*
Mark Anthony RUPA, *Division of Masbate, Department of Education, Philippines*

Abstract

The primary goal of teaching at any level of education is to bring a fundamental change in the learner. To facilitate the process of knowledge transmission, teachers should apply appropriate teaching methods that best suit specific objectives and level exit outcomes. Aside from appropriate teaching methods, instructional supervision is vital in the development of any educational programs. Many science teachers especially non-majors may not have mastered or developed sufficient skills for effective science teaching. This study aimed at identifying the effects of teaching practices of science teachers and their relationship with students' academic performance in science through instructional supervision. Ten teachers were observed for one semester to identify the different techniques and approaches they used in teaching Science using different instructional supervision techniques such as clinical supervision, self-directive supervision and informal supervision. Quantitative and qualitative techniques were used to analyze the data collected. The data revealed that majority of the science teachers used the traditional method of teaching and rely more on the curriculum material issued which resulted in poor academic performance of the students in Science after the semester. Only very few instances where the teachers used inquiry based approach, problem based learning and guided inquiry approach. The study also showed a statistically significant relationship between teaching practices and students' academic performance in Science. From the results and analysis, conclusion can be made that the performance of the students who were taught through inquiry based learning were better as compared to traditional method of teaching learning. It is very important to identify and test teaching methods that can be helpful in enhancing students' long term knowledge and overall performance. In light of the fact that learning is a process that involves investigating, formulating, reasoning and using appropriate strategies to solve problems, teachers should realize that it becomes more effective if the students are tasked to perform rather than just asked to remember some information. A typical learning environment with a presentation from the course teacher accompanied by a lecture neither promotes learners' participation nor build the required level of reasoning among students. Students build a better understanding of the main concepts more effectively when they are engaged to solve problems during class activities. The study recommended the need to improve the teaching practices of science teachers through learning action cell, lesson study and attendance in training workshops to increase their efficiency within the field of their work. The general model of teaching does not have a place in contemporary schools anymore. Times have changed, the same chalk and talk method used 20 years back cannot be used now, and thus schools need to change. Group projects, independent research studies, and technology is used which has created the need for teachers to act like a supervisor, a leader. Students are given a variety of learning experiences which are considered as a personal challenge, for e.g. conducting a seminar or workshop or putting on a play.

Back to programme

(P248) SUGGESTIONS FOR VIRTUAL LEARNING CONTENTS BASED ON A CASE STUDY OF AUGMENTED REALITY CONTENT IN KOREA'S 2015 SECONDARY SCIENCE CURRICULUM DIGITAL TEXTBOOK

Sonya N. MARTIN, *Seoul National University*
Ki Eun EOM, *Seoul National University*

Abstract

In the context of the development of information and communication technology and in response to the fourth industrial revolution, Korea has reorganized the national curriculum to enhance the capacity of knowledge processing for students to be prepared to live in the future society. In Korea, the development of various digital textbooks and smart education are being applied in various fields (Ministry of Education, 2012). Digital textbooks were commercialized in Korea in 2007. Digital textbooks are electronic textbooks in the form of interactive e-books. Compared to traditional textbooks, digital textbooks intend to improve student interest and understanding by incorporating images and texts using various multimedia. In addition, because digital books are available on portable tablet PCs, students can access more easily many textbooks in one source rather than carry many traditional textbooks. (Korea Educational Research and Information Service, 2016) Finally, digital texts can be used to support augmented reality or virtual reality activities where teachers and students interact with each other rather than simply receive information from one-sided multimedia materials such as photos and videos. An important aim for adopting digital textbooks is to create student-centered classrooms (Ministry of Education, 2017). Since 2010, 163 elementary schools (grades 4-6) and junior high school have served as research sites to pilot the use of digital textbooks (Korea Education and Research Information Service, 2014) In 2015, the Ministry of Education announced that both traditional textbooks and digital textbooks would be used in parallel to teach the 2015 revised science curriculum at the elementary and secondary levels. In this paper, we first discuss the difference between augmented reality and virtual reality. Then we report findings from our analysis of four digital science textbooks from elementary grades 1-3 and secondary grade 3 in which we categorized and described all Augmented Reality and Virtual Reality content..
Next, we report on the evaluation of the alignment of the contents in textbooks with the stated core competencies in the revised 2015 science curriculum. Finally, we describe general trends in the presentation and use of augmented reality or virtual reality content by comparing the contents of these four digital textbooks with examples from sources gather from other domestic and international digital textbooks. Our findings show that the contents of the digital textbooks aligned well to the core competencies revise 2015 science curriculum and that the augmented reality and virtual reality content was not dissimilar from content examined from other domestic and international sources. We provide examples of both benefits and challenges to using this content in science classrooms. Specifically, we raise some questions about the possibility that some augmented reality content could reduce students' content understanding, even while increasing their interest. We conclude by suggesting future research on digital textbook use in Korea focused on the development of content, exploring the learning effects when using these contents, and the impact of digital textbook use on the motivation of teachers and students.

Back to programme

(P264) CONSTRUCTIVELY ALIGNED TEACHING SEQUENCE (CATS): A TOOL FOR TEACHING ORGANISMAL BIOLOGY IN STEM SENIOR HIGH SCHOOL EDUCATION

Joyce MAGTOLIS, *Leyte Normal University*
Antonio BATOMALAQUE, *University of San Carlos*

Abstract
Benchmarking on international trends, Philippine education is set to attune with the 21st century skills of Information, Media, and Technology, Learning and Innovation, Effective Communication Skills and Life and Career. To advance the field of biology education in particular, this study provides innovative teaching – learning material compliant with the newly implemented K to 12 Curriculum in the country. This paper describes a developed and evaluated Constructively Aligned Teaching Sequence (CATS) on the structures and processes of animal organ systems in the K to 12 Senior High School Biology 2 STEM curriculum. Based on the theoretical and methodological assumptions of educational design studies, this study involved the development of teaching sequences based on four design principles: a survey on the teachers' perspective in addition to Duit's (2005) three design principles which are undergoing clarification and analysis of science content, investigation into students' perspectives, designing of learning environments. The study employed drawing method (Reiss and Tunicliffe, 2001), researcher – made pre-test/post-test, questionnaire, checklist, video-recorded lessons, and recorded interviews. Respondents were 47 university freshmen, who were currently equivalent to the Senior High School of the new K to 12 program and 10 science instructors of Leyte Normal University for the second semester of the School Year 2015 – 2016. Quantitative data was analysed using relative frequency distribution, percentage method, non – parametric test and t-test. Students' drawings, interviews and observations were examined by thematic method. The study consisted of preliminary, development, implementation and evaluation phases. The students' initial conceptions on organ systems and teachers' difficulty of teaching the topics were looked into during the preliminary phase. In the development phase, the students' initial conceptions, teachers' difficulty, content and performance standards of K to 12 curriculum were brought together as the inputs to CATS. This teaching sequence is grounded in the principles of Constructivism as a theory of learning and Constructive Alignment as a theory of teaching and material development. During the implementation phase, the developed and validated CATS was carried out by the researcher to the randomly selected class in the teaching of the organ systems. The effects of CATS during the evaluation phase was done through the analysis of the pre-test/post-test scores, students' drawings before and after the use of CATS, teachers' evaluation of the material and responses to the interview. Quantitative and qualitative data corroborated that the use of CATS contributed to the attainment of the students' learning outcomes. In the light of the findings, the study recommends further that CATS may be redesigned to further strengthen correct conceptions, enhance limited conceptions and remediate students' conceptions in conflict with the accepted biological concepts. CATS offers innovative teaching materials and also is an avenue for further research on its improvement such as construction, usage, handling, and storage of the student outputs. Future prototypes may be developed to address more strongly students' alternative conceptions through the applied design principles or add new principles.

Back to programme

(P283) ANALYSIS OF PHYSICAL AND SCIENCE EDUCATION INTERDISCIPLINARY LESSON PLANS IN US ELEMENTARY SCHOOLS

Myung-Ah LEE, *Indiana State University*
Elsun SEUNG, *Indiana State University*

Abstract

The purpose of this research is to explore the interdisciplinary lesson plans of Physical Education and Science Education in elementary schools in the United States. Both subjects have been less emphasized in school relative to other subjects like math and language arts. Regardless of the increasing trend of childhood obesity in the United States, the time allotment of Physical Education has been rapidly decreasing in elementary schools with even recess time being cut (CDC, 2016). There is an urgent need to increase student physical activity to meet the minimum of 60 minutes recommended per day (CDC, 2016). Also, due to time limitations, there is a critical need to integrate science content into other subjects to satisfactorily meet state and national recommendations that indicate science content should be studied in elementary schools. The interdisciplinary approach between Physical Education and Science Education can be a possible solution to improve academic learning in both subjects. We conducted the document analysis with data collected from academic and practitioner journals as well as web-based data sources for practitioners in both subjects. Once a lesson with an interdisciplinary approach was found, the content area experts for both subjects reviewed and confirmed to ensure it meets academic learning standards for Science Education (i.e., Next Generation Science Standards) and Physical Education (i.e., National Standards for PE). All confirmed lesson ideas were put into a table and categorized according to content topics for both subjects. The major findings are as follows: 1. A total of 63 interdisciplinary lesson plans were found from the Physical Education database. Few lesson topics were found from science practitioner journals. 2. A total of 11 science topics were identified as integrated to these Physical Education lessons. The most frequently used topic was Human Body (n=17), the second most frequent topic was Animal (n=14), and the next most frequent topic was Earth's Material and System (n=8). The topic of Forces and Motion appeared in 6 lesson plans and Ecosystem appeared in 5 lessons. 3. Physical Education lessons were categorized into four topics. Locomotor Skills was used the most (n=40), Non-locomotor Skills appeared in 22 lesson plans, Manipulative Skills was used in 7 lessons, and Fitness Exercises was used in 5 lessons. Only a few interdisciplinary lesson ideas for both Science Education and Physical Education were confirmed as good learning activities by researchers who are content experts in both subjects. Most lesson ideas were found in the Physical Education database, so there is a need for exchanging good interdisciplinary lesson ideas between both subjects. The findings of this study provide insight for teacher educators and in-service teachers who are interested in improving optimal student learning by developing interdisciplinary lessons in both Science Education and Physical Education.

Back to programme

(P287) DEVELOPMENT OF GAME-BASED SCIENCE SIMULATION FOR PROMOTING ELEMENTARY SCHOOL STUDENTS' LEARNING IN PLANT GROWTH

Daranee JAIMEETAM, *Khon Kaen University*
Niwat SRISAWASDI, *Khon Kaen University*

Abstract

Over the past few decades, digital technologies and learning resources have important roles in education, and recent research found that the digital technologies can effectively support teachers' teaching practices in integrating inquiry-based instruction into science class. Due to features of technology, the support of students' visualization and imagination skill is important for science learning in school science level. Moreover, technological tools could promote learning motivation and inspiration for students. Educational researchers mentioned that implementing technology-based learning environment could raise students' cognitive engagement and learning performance. Regarding rapid growth of learning technology in science, game-based simulation is an effective digital media for enhancing science teaching and learning through the combination of computer simulation and digital game. This learning technology could promote students' motivation and attitude as well as increase their comprehensive understanding of science concepts. As such, the researchers have developed a visual-aid learning technology of game-based simulation representing plant growth experiment and then implemented with 32 of 4th grade students in a public elementary school located in north-eastern region of Thailand. The students never have formal science class on the topic of plant growth and any learning experience with game-based simulation in science class before. This implied that their backgrounds had been heterogeneous before interacting with the simulation-based guided-inquiry learning in this study. This paper illustrated the proposed game-based simulation as innovative learning tool with guided inquiry learning, for promoting students' science learning in primary school. Moreover, the paper presents an investigation of affective channel result on students' perception and attitude towards the guided-inquiry science learning with a support of the proposed game-based simulation. The elementary school students were assigned to interact with the proposed simulation regarding guided-inquiry learning process within two weeks for one lesson. After finished the lesson, they were administered 21-items and 20-items perception and attitude questionnaire, respectively. For the perception questionnaire, it has 21 items which are divided into two scales, including learning experience (LE) (12 items) and overall impression (OI) (9 items). For the attitude questionnaire, it comprises 20 items and all items were classified into five scales, including scientific confidence (SC) (4 items), attitude to learning science with technology (ST) (4 items), confidence with technology (TC) (4 items), affective engagement (AE) (4 items) and behavioural engagement (BE) (4 items). The preliminary results showed that they expressed positive perceptions towards the guided-inquiry learning experience employing game-based simulation. Moreover, they expressed positive attitudes to investigate plant growth phenomena with the visual-aid game-based simulation. This indicated that the use of game-based simulation as an inquiry learning tool with the facilitation of teacher is an interesting way for promoting the learning of science experimentation for new-generation learners in 21st century education era. The main implication of this study is the

development of novel learning tool addressing science concept of plants growth for promoting students' science learning performance in elementary school science.

Back to programme

(P293) ENHANCING GRADE 11 STUDENTS' SCIENTIFIC CONCEPTIONS OF ANIMAL CLASSIFICATION USING INDUCTIVE INQUIRY

Thitaporn INNGAM, *Khon Kaen University*
Parichat SAENNA, *Khon Kaen University*

Abstract

The concept of animal classification is one of the most misconceived concepts in high school biology. This is often caused by everyday terminology conflicting with scientific nomenclature. This research aims to explore students' understanding of concepts relating to animal classification and how to enhance the scientific conceptions of animal classification using inductive inquiry. The study sample of students consisted of 31 eleventh graders. The research tools were as follows: 1) inductive inquiry lesson plans of animal kingdom; 2) twenty-one test items for scientific conceptions of animal kingdom. In addition, a survey instrument was also used to collect more information about character traits of organisms and concepts of classifications. The survey items included open-ended and true-false questions. The data was analysed by categorizing the respondents into 4 groups based on the level of understanding: scientific understanding (SU), partial understanding (PU), scientific misconception (SM), and no understanding (NU). The results of this research indicated that most of students had no understanding (83.87%; SU) of the conception of scientific animal kingdom before studying. Misconceptions that some students held were the result of terminology used in daily life. For example, they misunderstood a turtle to be an amphibian, crocodile an amphibian, an earthworm a reptile and they thought a whale is a fish, a dolphin is a fish, a squid is a fish, a seahorses is not fish (a seahorses to be an invertebrates, a penguin is a mammal, a butterfly and bat are an aves causing the wings are present etc. Moreover, they have misconceptions about bacteria is an animal, cyanobacteria is plant, algae is both plant and animal, amoeba are animals, paramecium are the one type of an animals, Protozoa is prokaryotic cell etc. Students had a better understanding of all concepts (87.09%; SM) of scientific animal classification after studying. However, the study found that even after instruction some students still had scientific misconceptions (48.38%). Persistent misconception were seahorses is not fish, penguin is not bird, turtle is not reptile, butterfly is classified an aves because having a wing. This suggests that conceptions held by students as a result of every day experience have a strong influence on learning about scientific animal classification. This also suggests that students perhaps come to the classroom with their own system of classification. However, inductive approach stimulates and promotes students learning by themselves. The results of this study will benefit teaching and learning important biological concepts.

Back to programme

(P294) SMARTPHONE-BASED CHEMISTRY LABORATORY LESSONS FOR PROMOTING MIDDLE SCHOOL STUDENTS' PERCEPTION AND ATTITUDE IN CHEMISTRY LEARNING

Banjong PRASONGSAP, *Khon Kaen University*
Niwat SRISAWASDI, *Khon Kaen University*

Abstract
For the past decades, science educators and researchers have attempted to develop innovative laboratory learning in chemistry for promoting students' comprehensive understanding in the connection of the subject matter with how the world works. However, many researchers found that students still have numerous learning difficulties and they often hold various misconceptions about chemistry. To eliminate this problematic issue, mobile technology has been recognized as an effective teaching tool in inquiry-based science learning setting. In context of Thailand, implementation of the mobile technology as a pedagogical tool to support inquiry-based learning in science was still limited. With the advancement of mobile and ubiquitous technology, one of an effective mobile digital technology that researchers, developers, and educators are paying attention to utilize it for innovating traditional chemistry class is smartphone technology. In science education, mobile technologies promise new and exciting opportunities for both teachers and learners in a climate of distributed, ubiquitous, informal learning supported by mobile devices and wireless communication. For formal science learning, mobile technologies use in science laboratory is gaining in popularity in both cutting-edge scientific research and technology-enhanced science learning. In this study, the researchers conducted a preliminary investigation to examine effect of smartphone-based inquiry laboratory on middle school students' perceptions and attitudes toward the laboratory. The findings of this investigation provided us as a basis to re-design and develop a blended smartphone-based inquiry laboratory by combining mobile hands-on physical and virtual simulation-based laboratory into guided-inquiry learning process as a novel learning experience for chemistry teaching and learning. The participant of this study included 43 of seventh-grade students, aged between 11-13 years old, in a local public middle school located at north-eastern region of Thailand. This study used two instruments for evaluating the middle school students' perceptions and attitudes toward smartphone-based inquiry laboratory lessons. The perception questionnaire consisted of 21 5-points rating scale items that focused on two perceptual constructs consisting; (i) learning experience and (ii) overall impression. Another, the attitude questionnaire consisted of 20 5-points rating scale items that focused on five constructs consisting; scientific confidence (SC), attitude to learning science with technology (ST), confidence with technology (TC), affective engagement (AE), and behavioral engagement (BE). This study reported a preliminary investigation of smartphone-based inquiry laboratory lessons on middle school students' perceptions and attitudes toward the laboratory learning. The findings show that they expressed positive perceptions towards the learning experience of smartphone-based laboratory, and impressed with the laboratory lessons. In addition, they expressed positive attitudes to the technology-enhanced chemistry learning with smartphone-based laboratory. This revealed that it is a challenge to use smartphone-based hands-on inquiry laboratory learning in physical and biological science as a pedagogy for new generation learners who have well digital skill in 21st century education era.

Back to programme

(P295) TO ELIMINATE STUDENTS' MISCONCEPTIONS OF HEAT TRANSFER: A DEVELOPMENT OF INTERACTIVE SIMULATION REGARDING DSLM APPROACH

Sureerat SATCHUKORN, *Khon Kaen University*
Niwat SRISAWASDI, *Khon Kaen University*

Abstract

Over the past decades, many researchers and educators have reported a worldwide problem that students at all level came to science class with common misunderstanding in science concepts and their misconceptions are highly resistant to change through un-design or traditional teaching in science. To solve these problems, researchers reported the successful on the use of dual-situated learning model (DSLM) for eliminating the misconceptions and enhancing students' conceptual understanding in science. Currently, interactive computer-simulated learning materials for science teaching and learning provide opportunities to better facilitate students' understanding of science concepts by visualizing the abstraction of science concepts into more concrete experience. Moreover, it could bring to change students' alternative conceptions into scientific conceptual understanding and advanced mental model of scientific phenomena. According to the above mentioned reasons, this study aims to specifically develop an interactive science simulation in physical science concepts of heat transfer through DSLM approach for guided-inquiry learning in science. This interactive simulation will be used to facilitate middle school students' learning in school science for enhancing their scientific conceptual understanding and promoting science motivation in future study. The DSLM includes six stages of instructional procedure: (1) examining the attributes of the scientific concept; (2) probing students' alternative conceptions; (3) analyzing which mental sets the students lack; (4) designing dual-situated learning events; (5) instructing with dual-situated learning events; and (6) instructing with challenging-situated learning events. Regarding the DSLM process, the development of interactive simulation could have a potential to eliminate and restructure their misconceptions in scientific phenomena. There are several educational values that computer simulation adds into science learning activities, especially in activity type of inquiry-based science. As such, this study developed an interactive simulation on the concepts of heat transfer and then implement to middle school students. The participants for this study included 129 of seventh-grade students in a local public school located northeast region of Thailand. They age between 13 to 14 years old and they never have formal learning experience on the topic of heat transfer before. To investigate the middle school science students' existing conceptions in physical science concepts of heat transfer, eight open-ended conceptual question items have been developed by the researchers regarding the dual-situated learning events about heat transfer proposed by She (2004). The exploratory result shows that the middle school students hold many types of misconceptions and incomplete conceptions in the physical science concepts related to heat transfer. Moreover, some of them had no conceptions about heat transfer even they have learned the concepts already. As such, the researchers illustrate a conceptual idea of designing an interactive science simulation addressing the physical science concepts of heat transfer for improving the students' conceptual learning performance, and it might enhance the change of student's misconceptions and their mental model development in science.

Back to programme

(P312) CASE-BASED AND EXPERIENTIAL LEARNING: ENGAGING PHARMACEUTICAL SCIENCES STUDENTS IN PHARMACOTHERAPY

Wei Xiu SUNG, *Nanyang Polytechnic*

Abstract

Pharmacotherapy is an essential module in Diploma in Pharmaceutical Sciences at Nanyang Polytechnic, Singapore. Graduates from this diploma enter the workforce into the healthcare sector as Pharmacy Technicians to dispense and counsel on the use of medications to patients. Therefore, the module pharmacotherapy plays a crucial role in bridging theory and practice. Traditionally, a case-based learning (CBL) approach has been employed to teach this module. While the case-based learning approach engages students in discussion and application of commonly occurring problems in real-life setting, the main challenge faced in this approach is the inability to get students to be confident and comfortable when it comes to dispensing and counselling medications. Hence, the aim of this study was to employ a combined case-based learning and experiential learning theory (ELT) methodology as a means of engaging final year students from Diploma in Pharmaceutical Sciences, Nanyang Polytechnic in an application-based module, Pharmacotherapy II. This module consists of nine 4-hour face-to-face sessions delivered over one semester. A total of 34 Year 3 students participated in the study from April 2017 to August 2017. A flipped classroom approach was deployed as pre-lesson topic sharing was presented by selected students to the class before the first section of tutorial was distributed. For the first section of tutorial, students had to identify prescribing errors in the prescription and make interventions where necessary. They were then required to role-play the dispensing scenario and upload the recordings onto Youtube. The second section of tutorial consisted of case-based studies where students worked on the questions and discussed the answers collaboratively in groups before submission. The final section of tutorial adopted an authentic learning approach where students would role-play an actual pharmacy work environment scenario depicted before uploading the recordings onto Youtube. Selected videos from each section were played in class for all to feedback and critique. The links to the videos were posted in Blackboard® for students to review, self-reflect and learn from one another. Individualized comments and feedback were made by the lecturer for each video clip. At the end of the semester, a questionnaire was administered via Google Forms to investigate students' responses to the teaching approach. The results indicated that students had a positive engagement with the module. 93.5% of students felt that the various activities engaged them in learning and 100% of students were confident of applying the skills acquired, through this module, in future. Overall, the approach was highly beneficial to the student learning experience. Further studies can be carried out to monitor their performance during Year 3 attachment to determine if this teaching approach results in an improvement in the confidence of the students when it comes to actual dispensing and counselling at the workplace.

Back to programme

(P321) TRENDS OF STUDENTS' PERFORMANCE IN SENIOR SCHOOL CERTIFICATE BIOLOGY EXAMINATIONS (2007-2016) IN ONDO CENTRAL SENATORIAL DISTRICT, NIGERIA

Mulkah Adebisi AHMED, *University of Ilorin*
Lukman YAHAYA, *University of Ilorin*
Abiodun Ademolu FAGBOLA, *University of Ilorin*

Abstract
Biology is a unique subject, the domain of all living things and its environment. Therefore, the importance of Biology cannot be over emphasized. Despite its importance, several researchers have investigated into the performance of students in this subject and affirmed declining trends in the performance of the students in Biology and other sciences. It is on this premise that this researcher looped at the analysis of the trends of Senior School Certificate Examination Biology (SSCE) by WAEC and NECO in Ondo Central Senatorial District in Ondo State, Nigeria. The purpose was to compare the results of the students in Biology WASSCE and NECO SSCE (2007-2016), and to find out the factors influencing their performance based on Biology Teachers' views. The study was a descriptive research of Ex-post-facto type. The purposive sampling technique was used to sampled forty-three (43) senior secondary schools out of seventy-five (75) schools in four (4) Local Government Areas of Ondo Central Senatorial District (Ondo West, Ondo East, Idanre and Akure South), Nigeria. Also, one hundred and fifty (150) Biology Teachers participated in answering an open-ended question item. The instruments used for data collection were proforma and Biology Teachers' Questionnaire (BTQ). In this study, four (4) research questions were raised and answered using frequency distribution tables, percentages, mean, and charts. The results of the study revealed that the mean score of performance of the students in Biology WASSCE (1513.00) was less than the mean score of students' performance in NECO SSCE (1751.00).This indicated that students performed was better in NECO SSCE than WASSCE. Generally, performance of students in both WAEC and NECO had not been following a regular pattern from 2007 to 2016. This inconsistency can be attributed to the pattern of students' enrolment and other factors. The students' attitude and their interest in the study of Biology were the most frequent factors identified in this study out of numerous factors affecting the performance of the students. In respect to the findings of this study, the following recommendations were offered in order to improve the students' performance in WAEC and NECO Biology examinations in secondary schools in Ondo State, Nigeria. Proper test should be conducted in order to shortlist experienced and qualified Biology teachers for employment; Biology teachers should manage their classes well so as to arouse the students' interest in order to change their negative attitudes towards learning of Biology; government should decree that both WAEC and NECO should operate on the same standard in terms of curriculum and marking schemes; government should make provision for adequate and effective laboratory equipment in order to encourage the Biology teachers to engage their students in practical exercises; and government should consider the teachers' welfare in terms of improved salary as paramount so that the teachers would not have excuses of not discharging their duties judiciously.

Back to programme

(P324) STUDENTS' PERCEPTIONS ON INQUIRY-BASED LEARNING FOR ORGANIC CHEMISTRY LABORATORY

Pek-Ling LYE, *Nanyang Polytechnic*
Jayden ANG, *Nanyang Polytechnic*

Abstract
Medicinal Synthesis and Purification Techniques (MSPT) is an essential module for students pursuing Diploma in Medicinal Chemistry (DMC) at Nanyang Polytechnic. This module prepares graduates for laboratory skills and knowledge in organic chemistry, which consists of synthesis, purification and analysis of organic compounds. These are vital and transferable skills in various chemical industries. The traditional expository "cookbook" laboratory lessons direct students to follow step-by-step procedures to reproduce predetermined experimental outcomes. This gives little space for students to explore critical thinking and informed-decision making, especially when met with unexpected scenarios or observations in the course of experimental work. There is an immediate need to redesign laboratory curriculum to infuse these elements of creative problem-solving in order to develop and sustain the 21st Century competencies. Inquiry-based learning has been found to be effective for developing higher order thinking and knowledge creation. Therefore, the aim of this study is to enquire students' perceptions on inquiry-based learning through a re-designed MSPT curriculum. The new curriculum replaces the traditional expository "cookbook" approach to inquiry-based approach, supported by student-centered activities, such as team-based, peer-lead, problem-based and collaborative learning. It also enhances timely feedback from instructors to maximize students' learning. MSPT is a full practical module which consists of ten six-hours face-to-face sessions offered to Year 2 DMC students in Semester 1. A total of 44 students participated in this study from April 2017 to August 2017. In this new approach, students were not given the step-by-step practical manual. They were required to read the pre-assigned materials before each session. The session began with students presenting the content covered in their pre-lesson reading to the classmates. Subsequently, team-based learning approach was employed to scaffold the acquisitions of relevant concepts. Ultimately, students worked collaboratively to design and execute an experimental procedure to solve a given problem. While the learning activities were mostly peer-lead, the instructor also gave timely feedback and addressed misconceptions. At the end of this course, they completed a survey based on their experience in this new inquiry-based curriculum. 94.6% of the students stated that they learn more by designing procedure whereas 91.9% said they know the rationale behind each experimental step. Furthermore, the number of students who considered themselves confident in designing experimental procedure has increased by 26.2% after this course. This study shows that students agree the new curriculum helps them learn deeper and better. It also indicates this pedagogy boost their confidence in pursuing laboratory work in organic chemistry. This finding implies that the new MSPT approach could be employed in other practical-based lessons to enable deeper learning through critical thinking and informed-decision making. Further studies is necessary to investigate the effectiveness of this new curriculum in developing problem-solving and knowledge transfer capabilities through students' final year projects.

Back to programme

(P328) ROLES OF AND INTERACTIONS AMONG STUDENTS WITH DIFFERENT COGNITIVE PREFERENCE IN PLAYING AN ECOLOGY TABLE GAME

Chun-yi CHENG, *National Taiwan Normal University*
Wen-Hua CHANG, *National Taiwan Normal University*

Abstract
Game-like learning activities are challenging and joyful for students. Students may develop domain knowledge as well as intellectual skills through engaging in game-like learning activities. Literature indicated that student's preferred mode of attending scientific information impact on what he/she does do when participating in learning activities, and lead to the various levels of academic achievement. However, few studies have investigated how heterogeneous groups of learners collaborate in solving problems and the role of their prior knowledge in developing situated understandings. This preliminary study was purported to explore the relationships between students' interactive behaviours and their conceptual learning during their participation in game-like collaborative learning tasks. Based on the responses of students from four classes on "the Biological Cognitive Preference Questionnaire" (Tamir, 1985; Cheng *et al*., 1997; Tseng, 2010), four heterogeneous groups of seventh graders (*N* = 16) were invited to participate. Multiple sources of data were collected. While the groups learned through a table game about Ecology, they were videotaped. The videotapes were transcribed, and analysed by applying constant comparative method to identify students' functional role, cognitive role, and interpersonal role (Abrami *et al*., 1995). Other data sources collected included pre- and post- test scores of individual student in a two-tiered test "the Concepts of Plants", student's written report of perceptions about the leaning activity, and group artefacts. After cross-checking the quantitative and qualitative data, it is revealed that (a) The groups, which showed effective cooperative learning features, and students with "Principles" cognitive preference, performed better in the two-tiered test; (b) The within group interaction process was composed of "Confusion", "Knowledge Exchange", and "Strategic Problem Solving" stages; (c) Students with "Questioning" cognitive preference tended to play the roles as "Leader" and "Answer finder" in the ecology table game, moreover, students with cognitive preference "Factual Information or Recall" tended to play the roles as "coupler" and "observer"; and (d) Most students reported positive attitudes toward the game-like learning activities, but not recognized the effectiveness of the activities in building their conceptual understandings. It is concluded that, although students are willing to engage in the game-like collaborative learning tasks, the students might pick a quick answer rather than reach conceptual understandings through group discussion. Moreover, the students in the groups with effective collaborative learning features benefit from the game-like collaborative learning activities. This is not necessary the case for their peers with higher pre-test scores. Finally, students' conceptions of effective classroom learning influence their willingness to participate. Based on the aforementioned findings, it is suggested that before applying the game-like learning activities, some training about interpersonal skills are needed. In addition, the role of students' conception of learning should be taken into consideration. This study will contribute to design and enact of game-like collaborative learning activities.

Back to programme

(P341) ESTIMATION OF THE VALUE OF ENVIRONMENTAL EDUCATION IN SCIENCE MUSEUM BY A CONJOINT ANALYSIS

Akihiro IIJIMA, *Takasaki City University of Economics*
Rina NAGASHIMA, *Takasaki City University of Economics*
Mamoru CHACHIN, *Gunma Insect World*

Abstract

Environmental education plays an important role in fostering of motivated human resources for making a sustainable society. In Japan, environmental education had been positioned as a part of school education until recently. However, currently adopted policy change in which an academic progress is emphasized has triggered reduced opportunities for environmental education. In this context, the role of social education is increasingly important for making up for deficiencies in environmental education at school. Science museums share a role in the environmental education by offering various learning programs relating to nature. However, many public museums in Japan are facing a shortage in operating expense. Because education is believed as one of the public services, its cost is not charged on the admission fee in case of the public museums. As a result, the public museums generally run in a red, and the shortage is covered by government disbursements. Therefore, the budget cut leads directly to the curtailment of educational services in the museums. In this study, we focused on the "real values of environmental education" offered by Gunma Insect World (GIW) which is one of the biggest public science museums in Japan themed on an entomology. GIW consists of an exhibition facility, a breeding facility, and 45 ha of natural forest, and offers a number of experience-oriented programs on environmental education. The educational programs can be classified into 5 attributes, i.e. "observation", "seminar", "activity", "interaction", and "quiz" dealing with insects. Conjoint analysis enables to estimate the value of educational services by each attribute as a monetary value. This method is one of the stated preferences established in the field of environmental economics. Questionnaire was designed with alternatives consisted of admission fee (cost) and package of different educational services offered (benefit). We obtained 389 valid responses from randomly selected volunteers from the guests in GIW. The values of respective attributes were estimated as marginal willingness-to-pay (MWTP: JPY / one group (up to 5 people)). For the indoor educational programs conducted in the exhibition facility, MWTPs were estimated to be 1,208 JPY for observation, 757 JPY for seminar, 1,119 JPY for activity, 1,237 JPY for interaction, and 240 JPY for quiz, respectively. On the other hand, for the outdoor educational programs conducted in the natural forest, MWTPs were estimated to be 1,462 JPY for observation, 717 JPY for seminar, 1,609 JPY for activity, 1,398 JPY for interaction, and 503 JPY for quiz, respectively. In total, the value of educational programs offered by GIW was estimated to be 10,250 JPY for one group. It corresponds to 205,000,000 JPY (ca. 1,810,000 USD) for annual admissions (100,000 people) in GIW, exceeding an annual operating expense of 171,000,000 JPY (ca. 1,510,000 USD). This indicates that the education has potentially great value although we generally take free ride on it. For the improvement and expansion of educational services, it is essential to estimate the real value of education quantitatively and acknowledge it in fair manner on the decision making of the management of museums.

Back to programme

(P346) THE STUDY OF STUDENTS' UNDERSTANDING IN NATURE OF SCIENCE

Kamonlapat PUENGPAN, *Mahasarakham University*
Kanyarat SONSUPAP, *Mahasarakham University*
Kanyarat COJON, *Mahasarakham University*
Somsong SITTI, *Mahasarakham University*

Abstract

Nowadays the nature of science (NOS) is a one of a main goal in science teaching and learning. This study aims to examine the student understandings in nature of science (NOS) of 43 grades 10th students in Mahasarakham, Thailand. The purposive sampling was use to select the sample. In order to obtain intensive data, the test consists of 8 open-ended questions about NOS that develop from Lederman and group covering 6 aspects of NOS; a definition of science, scientific process, tentativeness of scientific knowledge, creativity and imagination in science, laws and theories, and influence of society and cultures on scientific knowledge was used as a study tool. The content validity was checked by 3 experts which the IOC (index of Item-Objective Congruence) was 1.0. Data were analyzed by content analysis which divided into 3 groups; complete understanding, partial understandings and misunderstandings. The result indicated that a majority of student 62.46 percent held understandings in aspects of a definition of science and 30.92 percent held misunderstanding, however just 6.59 percent of students were partial understanding. In contrast in other aspects most of students saw partial understandings in the aspects of scientific process about 80.34 percent. There are 14.03 percent in the group of misunderstanding. Also found 5.63 percent in category of complete understanding. And in aspect of influence of society and culture on scientific knowledge major student held partial understanding about 79.12 percent. Nonetheless 10.76 percent experienced misunderstanding. It was also 10.12 percent in the group of complete understanding of this aspect. Moreover, it found that major percentage at 94.52 percent of student have misunderstandings in scientific laws and theories. Besides in the group of complete understanding rapidly reduced to 4.27 percent, and in the group partial understanding reached a bottom about 1.21 percent. Likewise, the percentage of the group who misunderstanding remained steady about 96.72 percent in aspect of tentativeness of scientific knowledge. It also fell to a low 1.22 percent in the group of complete understanding, and the group of partial understanding saw a minimal percentage about 2.06 percent. In addition, largely percentage of student in the viewpoint of creativity and imagination in science peaked at 88.78 percent in misunderstandings. Furthermore, the group of complete understanding the percentage only was 1.49 percent. On the contrary, it slightly went up to 9.73 percent in the group of partial understanding. It can be seen that from the result majority of student still possess misunderstanding in many aspect of NOS, such as creativity and imagination in science, tentativeness of scientific knowledge and scientific laws and theories. And only one aspect that major of definition of science that student held complete understanding so it is significant to improve student knowledge of NOS. The findings of this study are consistent to other previous studies in many cases. Finally, the study finding suggested that science teachers should focus and find proper teaching methods integrated NOS into the activities or instructions for developing students' understandings of NOS and promoting students to be scientifically literate persons.

Back to programme

(P347) THE STUDY OF STUDENTS' ACHIEVEMENT MOTIVATION IN PHYSICS

Peeradon ONSEE, *Mahasarakham University*
Kanyarat COJORN, *Mahasarakham University*
Kanyarat SORNSUPAP, *Mahasarakham University*
Somsong SITTI, *Mahasarakham University*

Abstract
This research aimed to study the achievement motivation of Matayomsuksa 4 student in physics classroom. The purposive sampling was used to select the sample to survey. The sample was 38 students of Matayomsuksa 4/3 in Phaduangnaree School, Thailand, spilt to 12 male and 26 female. The research instrument was 22 items of questionnaire which divided to 4 aspects, including aspects of decisiveness, responsibility, eagerness, and prediction. The content validity of the questionnaire was examined using IOC (Index of Item-Objective Congruence) by 3 experts which was 0.88 out of 1. The 22 items of questionnaire were given to these student to finish the questions without timing. The obtained data were analysed in order to study the mean values of the students' achievement motivation. The results of the achievement motivation were revealed as follows. First of all, the minimal aspect was the aspects of decisiveness which was 2.72 out of 5. This results indicated that they might have a problem with their decisiveness such as their confidence to answer the questions when they was ask by a teacher and they do not want the challenge and difficult work as an assignments. When considering each item, the question that have the lowest average value was "I always want to do the difficult and challenge work more than the simple work", which has only 2.24 out of 5. The maximum aspect was the aspects of responsibility with the mean values of 3.32 out of 5. This result indicated that the achievement motivation of this aspect was the only one that has a mean value more than 3.25. The question that have the most average value was "I will improve myself when I failed my exam", which was 4.05 out of 5. The less aspects were aspects of eagerness, and prediction, which have a mean values as follows, 2.85 and 3.04 out of 5, respectively. The values indicated that the students have an eagerness and prediction to do their work assignments and study which have nearly the same value. The question in aspect of eagerness that have the most average value was "I will continues and finish my work assignment even the environment surround me was not helpful", which was 3.40 out of 5. The question in aspect of prediction that have the most average value was "I am intended to get a good grade before I graduated from my school", which was 3.45 out of 5. However, the mean value of all 4 aspects were only shows in the medium level category that mean the achievement motivation of these Matayomsuksa 4 student might cause a problem in physics class. Therefore, the increasing students' achievement motivation of Matayomsuksa 4/3, especially in aspects of decisiveness, should be improved

Back to programme

(P359) THE RESEARCH ON LEARNING PROGRESSIONS OF CHEMISTRY CHANGE BY CHEMQUERY ASSESSMENT SYSTEM

Ying SUN, *Anhui Normal University*
Hualin BI, *Shandong Normal University*

Abstract
The research on learning progressions is an important topic in the field of international science education in the last decade, which promotes the development of science education research methods. Lots of studies have shown that the effective learning progressions for the big ideas are a critical path which promotes students' scientific literacy. NRC (2007) defined learning progressions as "descriptions of the successively more sophisticated ways of thinking about a topic that can follow one another as children learn about and investigate a topic over a broad span of time." The typical development models include BEAR, CCD and ChemQuery. ChemQuery is an assessment system that uses a framework of the key ideas in chemistry subject and criterion-referenced analysis using item response theory (IRT) to map students' progress. The purpose of this research is to investigate and characterize how students learn the big idea of Chemistry Change from pre-instruction to deeper understanding of the subject in their chemistry coursework by ChemQuery assessment system. The hypothesis is that as students learn Chemistry Change they build from experience and logical reasoning then relate chemistry specific ideas in a pair-wise fashion before making more complete multi-relational links for deeper understanding of Chemistry Change. This proposed progression of student learning, which starts at Notions, moves to Recognition, and then to Formulation and Construction. Basing on numerous literatures analysis and synthesis, and then hypothetical learning progression was developed in this dissertation research. In empirical research, the measurement instrument of learning progression for Chemistry Change was developed, and it used in Pilot-test I and II in order to modify hypothetical learning progression based on the analysis of data through Rasch modelling. This measurement instrument had good reliability and validity. The large samples were from high school students and freshman major in chemistry in university. In terms of quantitative and qualitative analysis of students' response, the research captured conceptual understanding progression, thinking characteristics and distribution in the different grades. The research results revealed that there were significant differences between different grades in understanding chemical change and showed that the students learn big idea of Chemistry Change which starts at Notions, moves to Recognition, and then to Formulation and Construction from pre-instruction to deeper understanding of the subject in their chemistry coursework. High school and freshman gradually improve the ability to understand Chemical Change, and built up a scientific conceptual understanding model. Grade 10 students appropriately stand in level 2, grade 11 and 12 appropriately stand in level 3 and freshman stand in level 4 of learning progression of Chemical Change. The study also finds that misconceptions are important stage when students develop their thinking and understanding. The research gained some valuable conclusions and provide important reference value for curriculum design and evaluation study.

Back to programme

(P364) A CROSS-CURRICULAR STUDY OF FISH ANATOMY AND COOKING

Taichiro GOTO, *Mie University*
Eimi NAKAMICHI, *Mie University*
Masachika KUNO, *Mie University*
Yuka ISOBE, *Mie University*

Abstract
To study comparative anatomy in animals, dissection activities have often been replaced by alternative methods in schools. Dissection activities are still controversial because they can be conflated with vivisection, which is not allowed. However, we can learn about vertebrate anatomy by dissection of whole fish, if teachers are addressing related safety issues.

We have been conducting since 2006 a cross-curricular lesson entitled "anatomy and cooking practice" that focuses on the study of fish anatomy and fish cooking in a middle school setting. One main purpose of the lesson is to make students better understand vertebrate anatomy through cooking. In Japan whole fresh fish can be purchased in conventional markets and subsequently be prepared by cutting it into fillets. Actually, middle school students learn how to prepare fish fillets in house economics. During the course of the study, we also aim for the students to have a feeling of appreciation for the animals eaten.

We conducted this lesson over two successive class periods, one dedicated to the study of anatomy and one to cooking in a middle school. As a material, we have been using rainbow trout that offer the following advantages; 1) they are cultured in Japan and easily available in supermarkets, 2) their body is covered with small scales that preclude hand injuries during manipulation, 3) their internal organization is easy to observe because of their large abdominal cavity, and 4) they are easy-to-eat because of their smaller bones and good taste. The lesson was aimed at second graders of middle school. A cohort was distributed over six 30- to 40-student classrooms. Paired students used one fish. Middle school teachers of both science and home economy classes were introduced to the procedure in advance and were supported during the practice by university students belonging to our teacher training course.

In the first trial in 2006, some students hesitated to dissect the fish, but most of them eventually became interested in the internal organs. They could understand the common features in vertebrates. Some students dissected to observe eyes and brain. After studying anatomical practice, they cooked and ate well the cooked fishes without remaining. A few years after the first trial, the following students have been looking forward to do this practice in the second grade. That practice using real fish has strongly impacted the middle school students. It also provided students of the teacher training course with an opportunity to practice cross-curricular lessons.

We also developed alternatives materials before dissection such as a hand-made fish anatomy model and a transparent gold fish which was cultured in our laboratory. We have used these alternatives as an introduction of fish dissection since 2016. The procedure of anatomical study should be carefully treated in a sequence of the practice.

Back to programme

(P372) SCIENTIFIC MENTAL REPRESENTATION OF CELL DIVISION IN 10 GRADERS USING MULTIPLE REPRESENTATIONS

Sirapprapha THONGPON, *Khon Kaen University*
Parichat SAENNA, *Khon Kaen University*

Abstract

Cell division is considered the most difficult learning challenges for high school biology students. It contains factual and principle knowledge. Conventional biology teaching tends to have students memorize the fact and processes of cell division. The aim of this study was to promote grade 10th students' scientific mental representation of cell division. Pre-experimental design with one group pretest-posttest design was used to collect data. Thirty-two 10th graders of purposive sampling were participated in the study. A series of multiple representations integrated with inquiry teaching models were implemented in the classroom. Drawing method with its explanations was used to access their scientific mental representation. The drawings were analyzed and categorized into different groups. The results showed that 50 percent of students were not able to scientifically diagram and describe the structure of DNA of the pretest. A simple DNA structure as a thread -like was represented from students in this group. Posttest evaluation found that 85.8 percent of students exhibited the scientific representation of DNA structure. It was found that they were able to scientifically diagram and describe DNA structure. They were able to explain the basic of DNA structure include phosphate group, identify type of sugar, and nitrogenous bases. They were able to identify the direction of polynucleotide of DNA. It was found that 84.4 percent were able to correctly distinguish between chromatin, chromatids and chromosomes. Students were able to scientifically diagram and describe the chromosome's structure. They were able to describe the relation between chromatin, chromatids, and chromosomes. Eighty-four percent were able to correctly diagram mitosis. A simple circle of mitosis cell division was represented in the posttest. Posttest evaluation, they were able to scientifically diagram the behavior of chromosome at different phrases. However, they were unable to identify homologous chromosome and sister chromatids even though that were previously able to describe and distinguish the different between chromosome and chromatid. It was found that only half (56.3%) could correctly diagram meiosis. The rest of students (43.7%) were unable to scientifically diagram the behavior of chromosome during meiosis cell division and made a connection between meiosis I and II. Students were found confused of technical terms, e.g. crossing over, chiasma, and kinetochore. It was found the students could correctly identify chromosome behavior in their diagrams of mitosis and meiosis. But, they had a challenge of scientifically describe it due to the confusion of the technical terms. Moreover, it was also found that the chromosome and its structure seem to be a key concept of the cell division for the students. The data suggests that students are unable to transfer exiting scientifically representation to a related concept. We conclude that teaching and learning activities that help students understand the terms and allow them to connect conceptual understandings of the processes involved in cell division are needed.

Back to programme

(P373) USING A VISUAL TOOL IN IMPROVING HIGH SCHOOL STUDENTS' CONCEPTUAL UNDERSTANDINGS AND SELF-GENERATION OF ANALOGIES IN ACID-BASE CHEMISTRY

Suttida THAMMAWIPAK, *Khon Kaen University*
Romklao JANTRASEE, *Khon Kaen University*

Abstract
Visual thinking is currently one of cognitive skills which have been recognised importance to help students use for representing their scientific ideas and explanations. Analogy has been accepted as a teaching tool which can help students improve their concepts scientifically. More importantly, generation of analogies provides teachers with a channel in seeking students' understanding and reflects how students think visually in learning chemistry. Chemistry is regarded as a difficult subject because it requires students to interconnect between macroscopic and sub-microscopic representation. The purposes of this research were 1) to study students' conceptual understanding and 2) to investigate students' self-generated analogies of acid-base chemistry. This concept is abstract, complicated, and incomprehensible for several high school students. The participants were 40 grade 11 students who studied at an extra large secondary school located in Kalasin, the northeast part of Thailand. A one group pretest-posttest design was employed to investigate students' conceptual understanding and self-generated analogies after participating an analogy teaching strategy. Results from testing using open-ended questions showed that, before using analogy, the concept of electrolyte and non-electrolyte solutions, most students had alternative concepts. In contrast to the concept of acid-base solutions and Arrhenius acid-base theory, most students had no understanding. However, after using analogy, a great majority of the students tended to have partial understanding on three mentioned concepts. These results indicated that they tend to have higher conceptual understanding level, since given analogies were enabled them to visualise complicate concepts. Although there was a student who was still no understanding on the concepts of acid-base solutions and the Arrhenius acid-base theory. Probably, he experienced confusion about using written language communication, since he thought that scientific language was similar to spoken words in daily life, such as substance and solution or ionization and dilution. Most scientific terminologies in textbooks were defined in Thai. Thus, he was unable to express their understanding correctly. In addition, results of self-generated analogy group revealed that most groups could generate analogies which were different from the lesson at high level on the concept of electrolyte and non-electrolyte solutions as well as acid-base solutions was high level. Interestingly, their analogies could be presented these concepts meaningfully. These implied that they were able to generate their own analogies and understand limitations of such analogies, because they were engaged to represent, explain, and discuss their analogs with peers in group throughout the analogy lesson. Unfortunately, some groups of the students were able to generate their analogies on the concept of Arrhenius acid-base theory partially. This generation of analogy was categorised at medium level, since they could compare some similarities and differences between analogs and targets. Although self-generated analogy is alternative route for a teacher to assess how students think visually, the further study should evaluate how students generate their own analogies to explain difficult concept individually. Moreover,

reflection from a teacher will help them metacognitively address their ideas.

Back to programme

(P374) IMPLEMENTING MODEL-CENTERED INSTRUCTION SEQUENCE TO IMPROVE HIGH SCHOOL STUDENTS' CREATION OF MODELS AND MODELING PRACTICES

Nutnaree KANAMUANG, *Khon Kaen University*
Romklao JANTRASEE, *Khon Kaen University*

Abstract
Scientific model has been considered to play a significant role for learning which can be used to assess how students understand phenomena. Providing students with experience in creating a model is to help them get involved in scientific modelling. Model-centered instruction sequence (MCIS) is an instructional strategy which places emphasis on creating scientific models and modeling practices. These practices require students to construct models, evaluate models, revise models, and use models to predict a new situation. The purpose of this study was to investigate effects of MCIS on students' abilities in creating scientific models and involving modelling process of vapour pressure. Participants were 28 grade 10 students who studied at a public high school. They did not gain experience with MCIS. Main data sources were collected from testing and worksheets. Results showed that MCIS could promote students' abilities in creating scientific models. In this study, a creation of scientific models was considered in two aspects including a pictorial and conceptual model. In pre-test, most students expressed pictorial models at good level because they could draw an evaporation picture at macroscopic level. However, their explanations in such a conceptual model were incorrect. They were categorized at fair level. Also, the relation between pictorial and conceptual models was at fair level, since they were unable to write explanations to be consistent with pictures. When comparing results from post-test, they improved their abilities at excellent level - they were able to draw more details related to evaporation, condensation, and equilibrium state at submicroscopic level in order to represent vapour pressure. They could also explain a picture with details and define vapor pressure correctly. In contrast to pretest, they could connect all parts of pictures to written explanations. Results from scientific modelling were analysed four mentioned processes. It was found that there was a model construction which was at fair level. They were unable to construct initial models based on their prior knowledge. Thus, their models did not express pictures which represent the amounts of water molecules at equilibrium condition and no related keyword. Interestingly, almost modelling processes (i.e., model evaluations, model revisions, and model predictions) were categorized at excellent level. It was possible that gathering data from doing an experiment and gaining scientific ideas during instruction helped them to evaluate initial models. Also, evidence from an investigation was useful for them to revise their mental models. They understood the connection among evaporation, the condensation and the amount of water molecules in equilibrium condition. Due to their understanding, they could use models to predict a new situation. This suggested that they could transfer their knowledge from creating initial models to explain vapour pressure of water and use it to predict vapour pressure of formic acid. Because the scientific modelling practices focus on the construction, use, revision and evaluation of models. Therefore, MCIS is an alternative strategy which is recommended for teachers to help students understand how scientists acquire scientific knowledge.

Back to programme

(P375) GRADE 11 STUDENTS' MENTAL REPRESENTATIONS OF PHOTOSYNTHESIS USING MULTIMEDIA-EMBEDDED-LEARNING SHEET

Sarunthorn INTHASIRI, *Khon Kaen University*
Parichat SAENNA, *Khon Kaen University*

Abstract
The development and use of information technology has been rapidly increasing in education due to its demonstrable value in helping students' learn. In the same way, this can improve the ability of learning and create their own explicit knowledge. This also enhances students' ability to use technology they already are familiar with for learning. Typically, a biology teacher in Thailand distributes a handout with texts and graphics as supplemented material during the class. In this study we developed a multimedia embedded learning sheet (MELS). Its aim is to supplement the textbook by supporting students' development of correct mental representations of photosynthesis. Two concepts of photosynthesis, Light Reaction and the Calvin Cycle, were developed as MELS. Each MELS contained an augmented reality (AR) visual graphic and an in-person quick respond (QR) code to communicate with the teacher. The text which corresponds to the motion graphic AR was designed using representative symbols and colour codes. The MELSs were reviewed by experts before implementing in the class. Pre-experimental research with one group post-test design only was used in this study. Purposive sampling of participants was employed to collect the data. Each MELS was provided as a handout for inquiry-based learning. After finishing the lesson, a drawing method was used to evaluate forty-seven 11th graders' mental representations. Data were gathered and analysed using a framework adapted from Brewer (1999) and Kurt et al. (2013). The results showed that 44.7 percent of the students were able to produce scientifically representative drawings of three or more the components of the Light Reaction. These include proteins positions in the thylakoid membrane, pathway of electron transport chain, molecules in the process of Light Reaction, Light Reaction influencing-factors, the Photosystem where light reaction occurs, and photolysis equation balancing. Yet for the Calvin Cycle more students (63.8 percent) were able to produce scientifically representative drawings of three or more concepts. These included the major pathway of Calvin Cycle, products, changes in high energy molecules, substrates and enzymes of Calvin Cycle, position where Calvin Cycle occurs and carbon equation balancing Calvin Cycle. Moreover, it was found that students' scientifically representative graphics corresponded with those of MELS. This suggests that the MELSs helped students gain a scientific mental representation. However, it was found that none of the students were able to graphically connect the Light Reaction and Calvin Cycle. Classroom observation indicated that the students were more interested in the motion graphics of AR than in reading the text. We conclude this learning method will be most effective when fewer concepts are used, as with the Calvin Cycle compared with the light reaction. The integration of the photosynthesis concepts is suggested for the development of a scientifically correct mental representation. In addition having MELS offline allows learning in the absence of internet connectivity, as is the case for many schools.

Back to programme

(P377) GETTING STUDENTS INVOLVED WITH SMALL-SCALE EXPERIMENTS OF INQUIRY BASED APPROACH IN CHEMISTRY CLASSROOM FOR IMPROVING CONCEPTUAL UNDERSTANDING

Chutika SRISAWAT, *Khon Kaen University*
Romklao JANTRASEEJ, *Khon Kaen University*

Abstract
Small-scale experiments with low-cost and available materials are an alternative way in teaching science. Providing opportunities for students to get involved with small-scale experiments of inquiry based approach by engaging them in seeking evidence, generating, explanation and extending the concept from their actions are to encourage them into creating new knowledge by themselves. Moreover, this approach provides students to collaboratively work with others to compare their understanding. This research aimed to study an impact of small-scale experiments of inquiry based approach on students' conceptual understanding of factors affected to chemical reaction rate. This concept is one of topics in a fundamental chemistry course. All students who studied in science-mathematics program at this school were required to study a fundamental chemistry course before studying other chemistry courses (e.g., chemistry 1-5). A total of 44 grade 10 students from a high school class participated in the study. This research was conducted by quantitative research method using quantitative approach with one group pre-test – post-test design. Data were obtained through a two-tier diagnostic test covering three sub-concepts related to such a topic. Students' responses from the test were classified into five groups of conceptions understanding levels and compared between the pre-test and post-test. It was found that, in the pre-test, the great majority of students had alternative conceptions on the concept of surface area and temperature affected to chemical reaction rate. For concentration affected to chemical reaction rate, less than half of the students had a partial understanding with specific alternative conceptions. Due to the nature of chemistry concepts in high school, it required students to explain the occurrences and changes of behavior of matters logically. These concepts were greatly difficult for them. Surprisingly, in the post-test, most students had alternative conceptions on the concept of surface area and temperature affected to chemical reaction rate. This might arise from the use of similar small-scale experiments for both concepts and results from given chemical reactions were hard to measure directly. Therefore, they experienced difficulty to generate explanations after inquiring. However, half of the students had complete conceptions on the concept of concentration of chemical reaction rate. They were able to explain why increasing the concentration of reactants tends to increase rate of chemical reaction. Possibly, experimental results were clearly observed, therefore students were able to formulate explanations from evidence as well as connect such explanations to scientific knowledge. When using Wilcoxon signed rank test, it was found that there was a significant difference ($Z = -5.174$, $p<0.05$). This suggests that an implementation of small-scale experiments of inquiry based approach can enhance students' conceptual understanding. Although helping students to learn sciences does not require well-equipped material laboratory, science teachers can apply locally available equipment to allow students to carry out experiments. More significantly, before implementing the small-scale experiments with low-cost materials, teachers should always repeat an experiment to assist students in understanding concepts.

Back to programme

(P378) A STUDY OF GRADE 11 STUDENTS' ANALYTICAL THINKING ABILITY AND LEARNING ACHIEVEMENT IN THE SUBJECT OF "ENDOCRINE SYSTEM" THROUGH LEARNING ACTIVITIES BASED ON THE SCIENCE, TECHNOLOGY AND SOCIAL (STS) APPROACH.

Ronnasit PRADUBSRI, *Khon Kaen University*
Phairoth TERMTACHATIPONGSA, *Khon Kaen University*

Abstract
Learning Skill will be the most important skill of living for people in Thailand in 21st Century. So there have to be a change in the management of learning in order for children in the 21st century to have the knowledge, ability for learning and necessary skills. The 21st century learning skill for people's lifelong learning experience consists of Critical Thinking, Communication, Collaboration and Creativity. Critical Thinking is the most important thing for Thai student in 21st Century. Learning activities based on the Science, Technology and Social (STS) approach will increase Thai students' analytical thinking ability. STS is the learning innovation which encourage students to take the problems they have around them to think analytically and then find the way to solve the problems by using the scientific process including using technology for solving the problem. This will benefit the learner and can be applied to the daily life of Thai students properly. The purpose of this research were 1) to study grade 11 students' analytical thinking ability in the subject "Endocrine System" through learning activities based on the Science, Technology and Social (STS) approach so that at least 70% of the students made a score of 70% of the full marks or better, and 2) to study the students' learning achievement in which it was prescribed that at least 70% of them made a score of 70% of the full marks or better. The target group consisted of 45 grade-11 students in Banphai School during the first semester of the 2017 academic year. The research was Pre - Experimental Research and followed the One - Shot Case Study Design procedure for which 2 categories of tools were used, i.e. experimental tool consisting of 4 lesson plans on the subject of "Endocrine System" based on the Science, Technology and Social (STS) approach to be used for 10 instructional periods, and data collection tool consisting of two 4-choice tests, i.e. 1) a 30-item analytical thinking ability test on the subject of grade-11 "Endocrine System" 2) a 40-item learning achievement test on the subject of grade-11 "Endocrine System". The collected data were analysed by applying basic statistics of percentage and arithmetic mean. The findings: 1) On the aspect of analytical thinking ability, it was found that 35 students (or 78% of the group) made scores higher than 70% of the full marks. 2) On the aspect of learning achievement, it was found that the student passed the prescribed passing criterion, i.e. 32 students (or 71% of the group) made scores higher than 70% of the full marks. The expected benefits of this research are 1) Teachers who have studied Learning activities based on the Science, Technology and Social (STS) can bring analytical thinking ability to apply with their life. 2) This research will be the guideline for teachers who have studied Learning activities based on STS approach to apply this learning management with the other contents and other subject accordingly for solving problems in their community and society.

Back to programme

(P385) BUILDING AN EFFECTIVE ASSESSMENT TO TEST THE APPLICATIONS OF PHYSICS CONCEPTS IN HIGHER ORDER THINKING QUESTIONS

Bernard RICARDO, *NUS High School of Mathematics and Science*
Andre JUSUF, *NUS High School of Mathematics and Science*
Choon Keat Paul LEE, *National Institute of Education, Nanyang Technological University, Singapore*

Abstract

Teachers should constantly search for better teaching and assessment approach in order for students to effectively learn concepts, especially science. They should continuously adapt and adopt approaches that are more suitable for students based on their learning ability. One of the most basic concepts in physics is mechanics. In this topic, common instruments such as the Force Concept Inventory (FCI) and the Mechanics Baseline Test (MBT) have been extensively used to assess high school and undergraduate student conceptual understanding (Hestenes, Wells and Swackhamer, 1992; Hestenes and Wells, 1992). In this study, we assessed the suitability of these two instruments on the degree of physics conceptual understanding of students of the NUS High School of Mathematics and Science, Singapore. We showed that NUS High students' score distributions tend to be on the high end and skewed to the left, especially for the FCI, suggesting that they could be categorised as high ability students. We also compared these students' scores to other schools' scores – from various high schools and universities. We found that NUS High School students performed significantly better than other high school students and that none of the other student groups from various universities performed significantly better than our students. Further, we also showed via post-test interview that the errors made by these high ability students, in general, do not reflect their lack of conceptual understanding but instead are due to other factors like carelessness and negligence. The findings in this study suggest that the FCI and MBT are effective to show that high ability students have a very good conceptual understanding, but might not be able to assess learning intervention or differentiate student conceptual understanding in a population of high ability students. As the instruments are known to assess student basic conceptual understanding, more advanced assessments should be given to high ability students to examine the depth of their conceptual understanding, as to what extent they could apply the concepts in higher order thinking physics problems. We are currently constructing an alternative assessments involving more open-ended questions and of those that make more use of mathematics (based on Ricardo and Lee, 2015; Ricardo, 2016). We expect that this would better allow us to understand our students' degree of transferability of their conceptual understanding to more advanced science problems or even to better discriminate their performance in assessment. In these instruments, open-ended questions are preferred as compared to multiple choice, in order to reduce some of the confounding factors we encountered when interviewing the students. This study has important implication on the approach taken by teachers to teach high ability students such as the use of mathematical inquiry in teaching physics concept. While the use of mathematical language has much been avoided by physics teachers in teaching basic physics concepts, we propose for it to be a powerful tool in teaching high ability students.

Back to programme

(P401) EXPLORING KOREAN SCHOOL PRINCIPALS' BELIEFS FOR TEACHING DIVERSE STUDENTS IN INCLUSIVE CLASSROOMS

Eunhee CHA, *Seoul National University*
Doo-sung LEE, *Seoul National University*
Sonya N. MARTIN, *Seoul National University*

Abstract
Science education reform has been a topic of significant discussion in many countries for the last two decades, but progress towards systemic implementation of reform teaching strategies including student-centered inquiry has been slow. Although a significant amount of research exists about science reform and teacher leadership, less is known about the roles that administrators play in supporting science teachers to implement pedagogical changes needed to lead efforts in science education reform. In the field of educational leadership, school principals have been shown to be a significant factor for determining whether school reform measures will be successful. For example, if administrators are to support teachers in their work, they need to understand teachers' subject matter and how it is taught, help them access needed resources, and give them opportunities to develop the knowledge teachers need to be successful. In Korea, reform measures targeting the improved teaching of science for diverse learners is increasingly an important topic in schools as the numbers of special education needs (SEN) students and culturally and linguistically diverse (CLD) students increases. This research explores school administrators' perceptions about diversity in Korean schools with a specific focus on understanding what challenges administrators face to provide adequate science education for diverse learners. In this poster, we first provide context for appreciating Korea's changing classroom demographics and increased emphasis on educating diverse learners in regular science classroom settings and we provide context about the role of administrators in Korean schools and describe their leadership roles in schools. We share findings from interviews with administrators in which we ask them to discuss their beliefs about the role of science education for diverse learners and to describe the challenges their teachers face when teaching science in inclusive classroom settings. We compare administrators' responses with responses from Korean science teachers to a previously developed survey focused on examining beliefs and self-efficacy for teaching science to diverse learners. Building from these findings, we offer implications about the role of administrators in supporting science education reform and raise new questions for future research focused on exploring how administrators learn to engage in reform efforts with science teachers in their schools. Other studies have shown that principals play an important role in leading initiatives to improve student achievement, in supporting systemic changes in the use of new instructional strategies and technologies, and in fostering positive relationships among teachers that enables teachers to take risks when asked to implement new initiatives. In addition, administrators play critical roles in connecting teachers and parents and setting a positive atmosphere within the school community. Understanding how administrators think about diversity and inclusive education is necessary for identifying challenges and strengths of current leadership models in Korean public schools. This work seeks to fill the void in the literature on the role of administrators in science education, offers implications for re-structuring administrative education programs, and suggests new areas for research, specifically around the roles school administrators' play in improving science teaching for diverse learners.

Back to programme

(P403) NON-FORMAL SCIENCE EDUCATION: THE RELEVANCE OF STUDY VISITS TO A CHEMISTRY LAB

Pipsa BLOMGREN, *University of Helsinki*
Johannes PERNAA, *University of Helsinki*
Maija AKSELA, *University of Helsinki*

Abstract

Goal and significance of the study: This study analyzes the relevance of study visits to a non-formal learning environment, a modern ChemistryLab Gadolin (University of Helsinki, 2018), from students' and their teachers' perspectives. The goal of the study is to find out which levels of relevance—i.e. individual, societal, and vocational—are experienced during study visits to a chemistry lab according to the students, and to determine if the students and teachers share opinions about the relevance. Also the influence of gender and previous interest in chemistry are examined. Non-formal learning refers to learning that occurs in different, less formal environment while formal learning happens merely at school and is based on a curriculum. (Eshach, 2007) Non-formal learning is therefore goal-oriented learning that is not guided by formal learning goals. In practice this means that the goals are set by the providers of the activity sets the goals of learning. (Werquin, 2007) According to relevance theory (Stuckey et al., 2013) teaching should be relevant at all levels of relevance both in present time and in future. Moreover this theory encompasses the intrinsic and extrinsic relevance of teaching. Methodology: The research was conducted as a survey for students (N=400) and their teachers (N=33). The survey is based on Stuckey et al.'s relevance theory (2013) and it consisted of structured multiple-choice questions as well as open questions. The open question responses to the questionnaire were analyzed trough theoretical content analysis. Findings The preliminary results show that, for students and their teachers, the learning was most relevant at the level of the individual. However, teachers find the visits more relevant than the students themselves. In addition, the societal level of relevance was more emphasized than the vocational level from both students' and teachers' perspectives. There are clear differences between the ones who reported liking chemistry as a school subject and those who did not. Students who like chemistry find the study visits a lot more relevant at every level of the relevance. There were not significant differences between genders, but the individual relevance was greater for girls than for boys. Furthermore the vocational relevance was greater for boys than for girls. Discussion and implications: The results of this survey will be used to develop the activities and operations of visiting laboratory ChemistryLab Gadolin in University of Helsinki.

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Back to programme

(P404) NON-FORMAL LEARNING ENVIRONMENTS PROMOTING TEACHER IDENTITY OF SCIENCE TEACHER STUDENTS: SCIENCE CLUBS AS A LEARNING ENVIRONMENT

Julia HALONEN, *University of Helsinki*
Johannes PERNAA, *University of Helsink*
Maija AKSELA, *University of Helsinki*

Abstract
Goal and significance: Science experts and teachers are increasingly needed in development of society and technology. With the weakening interest of children towards natural sciences, the number of experts will decrease. Supporting the teacher identity development of teacher students improves the quality of science education, which inspires children to study. The main aim of the study is to find out how acting in non-formal learning environments affect the development of teacher identity of teacher students and to use the results to develop teacher education to produce inspirational and motivating teachers in natural sciences. Many studies on teacher education emphasize the importance of identity in teacher development. (Beijaard, Meijer, & Verloop, 2004). According to Beijaard et al. more research is required on the concepts related to teacher identity and the effect of different contexts on the formation of teacher identity. McGinnis, Hestness, Riedinger, Katz, Marbach-Ad, & Dai (2012) argued that in order to make teacher education as effective as possible the interaction between formal and informal (non-formal) teaching in teacher education should be studied more at least from the following perspectives: • How do both formal and non-formal teaching experiences affect the development of the professional identity of teachers in natural sciences? • Is the combination of formal and non-formal teaching differently affecting teacher students whose backgrounds differ? • How does the length of non-formal science education experience affect the professional development of teachers? Methodology The main research method in this study is survey. The data was collected via questionnaires using four different scales measuring the development of different aspects of teacher identity of teacher students instructing science clubs. In addition to the survey the teacher students were interviewed and the interviews were analysed using theoretical content analysis. Initial findings: Instructing a science club positively affects the teacher identity of science teacher students. Previous experience of working as a teacher or working as an instructor in a non-formal learning environment decreases the effect of instructing a science club on teacher identity development. Especially self-efficacy related factors, for example scheduling or managing a classroom were emphasized in teacher students' answers. Discussion and implications: According to teacher students with previous experience in non-formal learning environments science club instruction developed different aspects of teacher identity than other learning environments, as the clubs last for several weeks, allowing the teacher to better know the group. More research is needed to thoroughly investigate the effects of different non-formal learning environments on teacher student's teacher identity development.

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Back to programme

(P405) TEACHING SCIENCE THROUGH ITS HISTORY – THE USE OF CLASSICAL EXPERIMENTS TO TEACH SCIENCE CONCEPTS AND NATURE OF SCIENCE

Chee Wan TAN, *Singapore Chinese Girls' School*
Xuehui Arlene PANG, *Singapore Chinese Girls' School*

Abstract

Proponents for teaching science through its history claim that science is best understood through such means, as opposed to logical sense-making using the scientific method (Conant, 1947), and that an awareness of the questions that prompted the investigation of scientific concepts promote better understanding of these concepts (Strong, 1950). Apart from its cognitive benefits, this approach is also theorized to be able to bring about increased motivation in the learning of science (Brouwer & Singh, 1983), and an understanding of science as a socially relevant subject (Aikenhead, 1974). While the inclusion of topic-specific historical content in classroom instruction has been found to increase students' understanding of the nature of science, no significant gains in terms of knowledge acquisition have been reported (Roach, 1993; Irwin, 2000; Lonsbury & Ellis, 2002). Nevertheless, Solomon, Duveen and Scot (1992) concluded through interviews with Middle School students that knowledge of the history of science could have an impact on bringing about conceptual change and understanding. In this study, we sought to investigate the impact of teaching with science historical content on (i) bringing about conceptual change and the (ii) development of scientific thinking, investigation and planning skills. Of interest was also the extent to which this approach would promote (i) the appreciation of science as a human endeavour, and (ii) the awareness that the "study and practice of science are co-operative and cumulative activities, and are subject to social, economic, technological, ethical and cultural influences and limitations" (SEAB, 2018). We designed lesson materials based on the early experiments that led to the discovery of the concepts and processes related to selected topics covered in the GCE O Level Science Syllabi e.g. osmosis, photosynthesis, digestion etc. Instead of reading historical content in the form of a story, or by discussing the ideas of the early philosophers and scientists, students were tasked to explore topic-/concept-related experiments in a chronological order and challenged to "think like early scientists". They were challenged into having to find words and ideas to provide explanations for the results of these experiments, in consideration of the conceptual and technological limitations of the time when these experiments were first conducted and when specific vocabulary for the targeted concepts did not exist. This approach is in line with the strong emphasis of the GCE O Level Science Syllabi on the understanding and application of scientific concepts and principles, and the assessment focus on skills, comprehension and insight in familiar and unfamiliar contexts. Data on students' understanding of the nature of science, key conceptual changes and skills development were collected by means of student self-reporting through pre-and post-surveys, face-to-face interviews and through the sampling of students' work. In this presentation, we will share our key observations on our findings.

Back to programme

(P408) DEVELOPMENT AND USE OF THE CASE-BASED REASONING MODEL OF INSTRUCTIONAL DESIGN ON CLIMATE CHANGE UNIT

Hyoungbum KIM, *Chungbuk National University*

Abstract

Having outlined the importance of the case-based reasoning theory, the objectives of this study are to develop a case-based reasoning instructional model focused on climate change for a high school Earth Science class in Korea and to study how students make sense of case-based reasoning approaches in regards to problem solving in earth science class. Therefore a designing process of the instructional model was conducted according to the research's basic procedure as follows. First, an initial case-based reasoning instructional model was designed, as shown, based on theoretical considerations of case-based reasoning and research of science instructional models. Second, the validity of the designed model was determined by experts in science education and applied in a school setting through discussing the strengths and weaknesses of the model. The field application was conducted by 28 sophomores from one science track class in an academic high school in Gyeong-gi province of Korea during 7 lessons of the Earth science I class (total 275 minutes) in the second semester of 2012. After the class ended, the participants were asked to answer a questionnaire about the lesson, and three days after the class, a semi structured one-to-one interview was conducted. Through the analysed result about the interview contents, the first modified case-based reasoning instructional model was suggested. Third, the validation method of the contents about the first modified case-based reasoning instructional model was used by experts' review used in validation of a model or an investigating tool in general research. In the other words, the experts' review method suggested the model and assessed it by asking questions to the researcher using a simple checklist. The researchers who participated in the review were 5 experts who work in science education, 3 of whom were doctors and 2 of whom were in the middle of the doctor's course. This procedure enables experts to evaluate the accuracy of the research process and results because it gives an inter-rater reliability of the study (Lincoln & Guba, 2000). Based on the merits and demerits and improvement points of the instructional model determined through this validation process of the model, the second modified case-based reasoning instructional model was developed. Results suggest that students showed interest because it allowed them to find the solution to the problem and solve the problem for themselves by analogy from other cases such as crossword puzzles in an aspect of students' awareness of the designed model. This means students are motivated to study and the process of selecting and organizing educational content and teaching methods has to focus on students' active construction of knowledge. Therefore, the case-based reasoning instructional model can help researchers, teachers, and curriculum developers better understand students' process of learning and developing scientific knowledge about climate change.

Back to programme

(P414) STRIVING FOR OUTCOME BASED EDUCATION THROUGH TEACHER PROFESSIONAL DEVELOPMENT: A CASE STUDY OF CHEMISTRY UNDERGRADUATE LABORATORY TEACHING

Chantima PATTAMATHAMMAKUL,
King Mongkut's University of Technology Thonburi
Chanen MUNKONG, *King Mongkut's University of Technology Thonburi*
Sailom SAMPANVEJSOPHA,
King Mongkut's University of Technology Thonburi

Abstract

This paper reflects a practical aspect of andragogic framework and its implementation on designing teacher professional development. It is believed that adult learners prefer self-directed approach and the need for their own professional development. It provides a hindsight analysis of teaching improvement process through professional development activities of a group of chemistry teacher who taught first-year chemistry laboratory. This paper illustrates the stages of on-the-job training, in which a team of facilitators supported the teachers to change their teaching approach. The combination of the supporting team played different roles to ensure that the teachers had control over their own teaching, learning while actively participating in activities. At the preparation stage, the need is defined based on evaluation of students' performance after completion of the laboratory. Initial requirement of the teachers' need is to learn to teach better for expected learning outcome. The supporting team thus link professional standard framework for teaching and learning with their classroom practice in order to address student learning outcome. The extent to which students failed to achieve or retain core laboratory skills was intensively discussed. Questions were presented to the teaching team and allowed group discussions to occur. The teachers' sense of autonomy was prioritized so that every teaching team member was an active contributor - in every steps - towards their teaching development. Three key principles - skill-oriented learning outcome, engaging instruction and authentic assessment – were deployed to redesign the course syllabus. Consequently, the objectives and the scopes of teaching improvement were defined and agreed by the teaching team. The must-know content and the nice-to-know content were clarified. At this point, their major concern with class management was still time for 'pre-lab brief' session. Teachers' After Action Reflections (AAR) provides evidences to the way in which this specific learning community contributed to positive changes. For example, as the teaching team worked hard to spell out the expected learning outcomes, at the preparation stage, they remind one another to commit to their new teaching practice towards learning outcomes. Lesson-plan and theoretical content were adapted so as to maintain the goal. The AAR results in encouraging teachers' learning community; promoting teachers' acquisition of pedagogical content knowledge and skills: increasing awareness among teachers who collaboratively put effort to make laboratory teaching a student-centered lab. Teachers began to demonstrate the acceptance of learning facilitator approach and discarded some of their teacher-centered behavior. Gradual change occurred when professional development scheme acknowledged teachers' need and facilitated self-directed learning in real-work context. Confirmation of positive changes was undertaken with student feedback that given by three focus group discussions. Meaningful reflections of students provided not only rationale for further improvement but

also motivation for the teaching team to maintain their professional development aligned with Outcome Based Education. Students' recommendations, the challenges of workplace, workload management and re-learning how to teach; these are crucial factors that could promote or inhibit teacher professional development.

Back to programme

(P421) MAKING PRE-SERVICE SCIENCE TEACHER EDUCATION MORE RELEVANT: INTEGRATED AND PROJECT-BASED COURSE COLLABORATION BETWEEN UNIVERSITY AND UPPER SECONDARY SCHOOL

Outi HAATAINEN, *University of Helsinki*
Topias IKÄVALKO, *University of Helsinki*
Maija AKSELA, *University of Helsinki*

Abstract
Goal and significance: This study investigates the relevance of a course for pre-service science teacher education focusing on project-based learning (PBL) and collaboration with upper secondary schools. This is a part of a larger design-based research that aims to increase relevance of teacher education. To increase the relevance of science education as is recommended by researchers and educational reforms (e.g. NGSS 2013; Stuckey, Hofstein, Mamlok-Naaman and Eilks, 2013), teacher education should first be developed accordingly. An efficient way to ensure pedagogical models transferring into classroom practices is a long-term training that includes practicing, reflection and offers peer support (Van Driel & Berry, 2012). Course description: The developed course is a collaboration between The Science Education Centre at the University of Helsinki and the upper secondary schools of City of Espoo. The course is open for all subject teacher students in order to promote interdisciplinary. The course was piloted in spring 2017 and is currently run for the second time. The University course contained two parts. 1) university students design a PBL course about global challenges for the upper secondary school students 2) The "Global challenges" course is executed with university students as teachers. Methodology: To determine the pre-service teachers' views of the relevance of the course multiple data was collected from the pilot course: students' (n=25) essays, researchers' notes on feedback discussions during the course and collectively written course feedback on online whiteboard. Data from the on-going course include an online survey (n=7). More data from the ongoing course will be presented in the conference. The dimensions of relevance by Stuckey et al. (2013) was used as the base for the theory driven content analysis. Initial findings: Findings show that the majority of the relevance of the pilot course was individual (72 % of the students) and vocational (72 % of the students). Individual relevance related for example to personal interest on PBL, collaboration and independence of students. The collaboration with other pre-service teachers and the authentic experience of teaching were regarded highly beneficial for professional growth. Initial findings were similar for the on-going course. In both data samples only few mentioned relevance of societal dimension. Discussion and implications: The initial findings indicate this course is relevant for students personally and for their professional growth. In the future the researchers will investigate the relevance of the course for other stakeholders, i.e. high-school students and organizing institutions. This is needed to better determine the relevance of the presented model.

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Back to programme

(P425) STRENGTHENING OF EXPERIMENTAL SKILLS THROUGH UNDERSTANDING OF RATIONALE

Thomas LEE, *Yuan Ching Secondary School*

Abstract

With the increased emphasis of acquiring soft skills, 21st century competencies such as Critical and Inventive thinking and promoting inquisitiveness in students, we recognise the need to review the effectiveness of teaching approaches to strengthen students' laboratory experimental skills, in particular skills involving planning of investigations. Challenges faced by our students in their planning tasks have also motivated us to explore different strategies to improve their planning skills. Millar (2004) stated that effective tasks in practical work are those where students are not only hands-on but also minds-on. This led us to design a lesson package which aims to strengthen our students' experimental (planning) skills through understanding the rationale behind the procedural steps involved in experiments. A lesson study was conducted for 40 Secondary three students. They were taught to prepare a soluble salt by reacting an acid with an insoluble base. In a classroom setting before the practical lesson, students were shown a video demonstration on the preparation of zinc chloride by reacting hydrochloric acid with zinc oxide. That was followed by group discussions which were scaffold by questions on the rationale behind the procedural steps involved in the experiment. Students presented their rationale to their peers and the teacher went on to clarify any misconceptions. A day after, the students conducted the same experiment from the video in the laboratory. Formative assessments were administered after the classroom lesson and practical lesson, and students also filled up a student perception survey after the lessons. Results from the formative assessment showed that majority of the students were able to state the steps involved and its rationale when asked to prepare for a different soluble salt. Most of them were also able to extend the knowledge learnt to a planning task which involves the preparation of sugar crystals from sugar cane solution. From the survey, more than two-third of students agreed that they know the steps involved in the experimental method adopted after watching the video demonstration and conducting the experiment. More than 70% of students agreed that they understand the rationale after the group discussions and while conducting the experiment. When asked if they are confident to carry out the experiment on their own, only less than half the students thought they are able to. In general, students are receptive towards learning experimental skills through video demonstration, teacher's explanation and peer group discussions of the rationale. This study shows that allowing the students to understand the rationale behind procedural steps before conducting the experiment has a potential to strengthen students' experimental skills, in particular, their planning skills. In addition, this teaching approach could be used together with other training strategies to further enhance students' performance and skills in practical tasks.

Back to programme

(P426) EFFECTIVE USE OF GOOGLE DOCUMENTS IN COLLABORATIVE LEARNING DURING A SCIENTIFIC THINKING

Ying Yang TAN, *Yuan Ching Secondary School*
Jiawen ZHANG, *Yuan Ching Secondary School*

Abstract
Web 2.0 tools are instrumental in promoting Communication, Collaboration, and Information Skills of the 21st Century Competency. Google Documents, a Web 2.0 tool, was used as a tool in the effective administration and monitoring of students' learning during scientific thought experiments in Yuan Ching Secondary School for since 2014. Implementation of these tools was carried out to ascertain the efficacy of the usage of Google Documents for the completion of the Scientific Thinking Project. The effectiveness of the usage of the tools were also gathered with feedback from teachers implementing the lessons. All Secondary One students in the school since 2010 have worked on the Scientific Thinking Project, in which they apply the Scientific Thinking Method and learnt how to apply the concept of variables to a scientific thought experiment. In the project, students were to get into groups and record responses to a valid scientific question crafted by the students themselves. With the scientific question in mind, students were tasked to complete a scientific thought experiment, identifying the variables and if possible conduct the experiment on their own. Students also have access to a set of rubrics that was crafted to ensure that they are able to fulfil the criteria of the project. Subsequently, students are tasked to present their scientific question in an appropriate format, such as Microsoft PowerPoint or Prezi. The presenting group's classmates will have a chance to critique on the validity and soundness of their presentation. With refinement to the administrative processes using Google Documents, teachers found that students engaged actively in collaborative learning. They worked in groups with their peers, and the key advantages of using Google Documents were to view concurrent responses from other groups in their class. Students who went through this project were also able to form up different aspects of a scientific thought experiment on real-life examples, such as the hypothesis, dependent, independent and constant variables. Based on the information captured, teachers were able to carry out formative assessment promptly. This is achieved effectively by the teachers through identification of any errors in the identification of the variables and give feedback on any learning gaps in the scientific thought experiment. The use of Google Documents also allowed for the ease of any follow-up by the conducting teacher on eight groups in a typical class of forty during the oral presentations of the groups on their Scientific Thinking Project. New teachers that were inducted in the recent years were also able to quickly use the template in the implementation in their class. This long term study on the use and refinement of the usage of Google Documents as the collaborative tool for use in this context serves as one template for use in any group work in schools.

Back to programme

(P427) TEACHERS' PEDAGOGICAL CONTENT KNOWLEDGE AND DESIGN CAPACITY FOR SCIENTIFIC EXPLANATION

Elisa IZQUIERDO-ACEBES, *University of Cambridge*
Keith S. TABER, *University of Cambridge*

Abstract
Within the last few decades, science education literature has echoed reform documents' increasing emphasis in the creation of learning environments which spotlight science practices as a pathway to enhance scientific literacy. Explanation construction is one of these essential science practices, since it gives students opportunities to strengthen their content knowledge and gain deep insight into the nature of science and the practices and values of professional scientists.

Some studies have suggested that science teachers need to have a range of appropriate pedagogical strategies to create learning environments that support explanation construction, and that this Pedagogical Design Capacity is highly influenced by their Pedagogical Content Knowledge (PCK).

There are virtually no existing examples of studies whose goal is to conceptualize teachers' PCK for scientific explanation, and its impact on the design and implementation of explanation-based learning environments. To address this gap in the research, I ask the following research questions:

1. What are the minimum conditions and structures that enable and support the creation of explanation-friendly learning environments?
2. What is the relationship between teachers' Pedagogical Design Capacity and their PCK for scientific explanations?

The present paper discusses provisional findings for research question 1.

A total of six science teachers from two contrastive Secondary schools in Spain volunteered to participate in the project. The participants had different backgrounds and a wide range of expertise in the field of science education.

Main data sources for this study included audio-recorded lessons, in-depth semi-structured interviews (with five of the participant teachers) and researcher's field notes. This multiplicity of sources was conceived to enhance the validity of conclusions.

The process of analysing cases occurred in multiple steps. Each case was first analysed separately. Then, a cross-case analysis was conducted to identify common and different themes among all the cases.

I began by developing a coding scheme that was informed by current research on PCK, scientific explanation and Pedagogical Design Capacity. After the initial coding, I wrote a summary profile (within case analysis) for each participant to describe their knowledge and beliefs about scientific explanation in science classrooms, their orientations towards the teaching-learning process, their instructional strategies and how they adapt and mobilise science curriculum materials to engage students in explanation building.

In the second phase of data analysis, I conducted a cross-cases analysis of the six participants, examining the data set for patterns and themes to emerge. Through this iterative process of coding, displaying, and verification, I have developed a proposal about what are the necessary conditions that promote, nurture and sustain explanatory practices among students.

Provisional analyses suggest that episodes of explanation construction can only be found in real settings if students are given opportunities to engage in open-ended inquiry activities in a social context with the explicit epistemic goal of producing scientific explanations. This requires: 1) the classroom cannot be dominated by a teacher-led structure that focuses on the facts and follows the pattern of teacher Initiation, student Response, and teacher Evaluation; 2) the classroom itself must be seen by students as a community of practice, with democratic norms of responsibility and tolerance, and in which students are encouraged to work collaboratively; 3) explanation construction must be considered not an as additional peripheral aspect of science, but as an instructional goal itself.

To promote and support these learning environments, teachers must: 1) feel confident about their purposes and the way to put them into practice; 2) feel a certain degree of freedom and support from the school's management team, as well as from the student's parents; and 3) have a strongly developed Pedagogical Content Knowledge, with a high level of integration between components.

Extending research in these areas -including an understanding of the nature of teachers' PCK of explanation, how it develops over time, and how it relates to other knowledge components -such as Pedagogical Design Capacity- would provide a grounded basis to develop high-quality teacher education programmes. Such programmes would not only be conceived to attend to prospective teachers' needs, but would also be in healthy equilibrium with current science education reforms.

Back to programme

(P428) WHAT ARE THE PERSPECTIVES OF (A) PRIMARY 3 STUDENTS AND (B) SCIENCE TEACHERS ON THE RELATIONSHIP BETWEEN PLAY AND THE LEARNING OF PRIMARY SCIENCE IN SINGAPORE?

Woei Yng TAN, *University of York*

Abstract

Play, an activity, is often associated with children in the early childhood years (3 to 8 years old) than the middle childhood (9 to 11 years old). Play is fun and enjoyable; often resulting in child-initiated learning, which could in turn support children's scientific development. Interest in this research study came about when an incongruence in the teaching and learning style of students entering Primary 3 (P3) (age of 8-9) was noted at this level; the students who were trying to adjust to the more formal methods of teaching in P3 were doing Science formally for the first time. As Singapore is one of the countries which has Science taught as a formal subject later in the years as compared to children in other countries such as the United Kingdom who starts from the age of 5, these children have missed the period for them to play and learn Science in a playful manner. This research study aims to look at the extent and impact of using play as a pedagogical tool as well as the teachers' and students' perspectives of play and the learning of Primary Science for P3 students in Singapore. A mixed-method, case study research was used, where 15 minutes of free play was incorporated into 4 science lessons and observational data in the form of video and audio recordings were collected from 5 classes of children in 3 schools (a total of 183 children). 5 P3 Science teachers were interviewed using semi-structured interviews individually, one time before the first play session and after the last play session. 3 groups of students in each class (n=15) were purposively sampled to participate in Focus Group after all play sessions. Emerging themes from both findings suggest the feasibility and the value of using play as a pedagogical tool in our Primary Science classrooms in Singapore, catering to almost all students. For the Focus Groups, findings indicate an increase and sustained motivation for the young children learning Science, providing some affordances such as self-directed learning and creativity in application of what they had learnt; possibly results of the free-choice play that the students had engaged in. For the teachers, the affordance of Play, a shift in the teacher's teaching style to a more student-centred teaching method and the practical issues revolving around the implementation of Play will be discussed. With the students and teachers' perspectives being looked at and studied, the findings could contribute to the understanding of how future play-based Science lessons could be possibly designed and carried out.

Back to programme

(S240) ESTABLISHING AND REALISING A VISION FOR PCK RESEARCH IN SCIENCE EDUCATION

Symposium Integrative Summary
Pedagogical content knowledge (PCK) was a construct first introduced in 1986 by Lee Shulman to acknowledge the unique professional knowledge skilled teachers use to teach specific content to particular groups of students. Although the idea of PCK has heavily pervaded the science education literature, divergent views in understanding and interpreting PCK have restricted its utility in research, teacher education and policy (Settlage, 2013). Two recent meetings of researchers in science PCK, known as the PCK Summits, have attempted to address this issue. In the first PCK summit in Colorado in 2012, a group of PCK experts met and proposed a consensus model for teacher professional knowledge and skills, including PCK (Gess-Newsome, 2015). This model was further refined in the second PCK summit held in the Netherlands in 2016. The refined model has delved deeper into the nature and characteristics of PCK to reposition it within the professional knowledge of teachers. The revised model has also clarified the meaning of various terminologies associated with the PCK construct, allowing not only greater cohesion, but clarity around future thinking related to research in the PCK field. This symposium brings together participants of the second PCK summit. The first paper presentation describes the aim, the process and the outcome of the summit. It aims to provoke discussion about the Revised Consensus Model of PCK. The second paper systematically reviews the methodologies researchers used for investigating science teachers' PCK in published PCK studies based on the new terminologies in the Revised Consensus Model of PCK. It aims to identify commonalities and differences among the diverse approaches used for investigating science teachers' PCK. The final paper takes a more specific focus and describes the main approaches for capturing PCK from a dynamic perspective. It highlights the affordances and constraints of these approaches to capturing this variant of PCK. Collectively, these three paper presentations distill the insights from the second PCK summit and bring clarity to the different ways of investigating science teachers' PCK. This symposium would be of interest to researchers, professional developers and teachers who are interested in knowing more about the professional knowledge of teachers and/or designing research related to PCK.

Back to programme

(S240) ESTABLISHING AND REALISING A VISION FOR PCK RESEARCH IN SCIENCE EDUCATION

Symposium Paper 1
The second PCK summit: process, models and more

Jan van DRIEL, *The University of Melbourne*
Rebecca COOPER, *Monash University*

Abstract
Introduction & Study goals: Since its introduction, pedagogical content knowledge (PCK) has been widely written about in the science education research literature. This paper reviews and draws together the discussions from the second PCK summit that was held in Leiden, the Netherlands, December 2016. This PCK summit was designed to provide international researchers working on PCK in biology, chemistry and physics education the opportunity to share 1) how their data from PCK studies were collected, 2) the different kinds of instruments used to collect these data, and 3) the procedures used to infer PCK from these data. The aims of the summit were to develop a shared set of criteria to identify PCK for each kind of instrument through collectively analysing data that were obtained with the respective instrument; make accessible and comprehensible these instruments to the wider PCK research community and reach consensus on a model of PCK that is strongly connected with empirical data of varying nature, and can be used as a framework for the design of future PCK studies. As part of the aims, both summits included as participants experienced and early career PCK researchers, offering an opportunity for early career PCK researchers to be introduced to more experienced members of the PCK research community. As an international research community, the PCK research community is thinking forward about the future of research in this area and assisting early career researchers to better plan and appreciate the trajectory of research in this field. Methodology: The summit consisted of participants working in small groups with a focused task, alternated with whole group sessions. The focused tasks were determined by the two facilitators of the summit, in consultation with the summit organising committee. These tasks were strongly driven by the discussions and outcomes of previous sessions to ensure that progress was made over the course of the summit. The whole group sessions were moderated by the two facilitators during the first half of the summit however, these whole group sessions evolved and followed a more open format during the second half of the summit. The summit concluded with a model building session that included all participants. Findings & Discussion: The findings from this study include a Revised Consensus Model of PCK that will be presented at this session. It is hoped that the presentation of this model will generate thoughtful discussion from the participants at the session. Further findings include the significance of the processes involved in planning and carrying out the summit. These processes are valuable in relation to the sustainability and cohesion of a research community so that there is consistency around the quality, validity and reliability of research in the field. Implications & Significance: This paper opens up discussion around the process related to the planning and implementing of these summits in relation to the contribution they can make to the wider PCK research community in terms of offering not only greater cohesion, but clarity around future thinking related to research in this field.

Back to programme

(S240) ESTABLISHING AND REALISING A VISION FOR PCK RESEARCH IN SCIENCE EDUCATION

Symposium Paper 2

Literature review of methodologies used for investigating individual science teachers' pedagogical content knowledge

Kennedy CHAN, *The University of Hong Kong*
Anne HUME, *University of Waikato*

Abstract
Introduction & Study goals: This study presents a systematic review of the science education literature to identify methodologies used for investigating science teachers' pedagogical content knowledge (PCK). We focused on studies that investigated individual science teachers' PCK (i.e., teachers' individual PCK/practice PCK in the Revised Consensus Model of PCK (see also the third presentation)). We conducted a broad search of the literature from 2008 to the present to comprehensively explore how science teachers' PCK was investigated since Abell's (2007) call for greater unanimity in approaches to empirical studies in the field. Methodology: We followed the systematic review process outlined by Bennett, Lubben, and Hogarth (2007), which involves the following sequential stages: (1) identifying the review topic areas, (2) identifying the review research questions, (3) developing inclusion/exclusion criteria, (4) searching systematically electronic databases, (5) coding studies, (6) producing an overview/systematic map of studies, (6) reviewing in-depth the studies. We conducted searches in fourteen peer-reviewed journals in the field of science education and teacher education. 95 articles were selected for review. We then systematically analysed each of these articles in terms of (1) the major purpose of the study, (2) the research sample of the investigation, (3) the conceptualisation of PCK in the study, (3) the variants of PCK under investigation (e.g., static (i.e., planned) and/or dynamic (i.e., enacted)) and (4) the tool(s) researchers used to determine science teachers' PCK. Findings and Discussion: We only present the major findings below. Further findings will be presented at the conference. • About one third of the reviewed studies aimed to elucidate the nature of science teachers' PCK. The primary research focus of the other studies included, for example, exploring the development of science teacher's/teachers' PCK, studying the relationship between PCK and other variables (e.g., student achievement). Most of the studies adopted qualitative approaches in their investigation. • The location of the PCK studies was diverse, spanning across six continents. The sample size ranged from 1 teacher to 631 teachers. About half of the studies had sample size with less than 50 teachers. In-service teachers at the secondary level were the most commonly researched group. • The most commonly used PCK model is the transformative model by Magnusson, Krajcik, & Borko (1999). An increasing number of studies were conceptually grounded in the consensus model emerged from the first PCK summit (Gess-Newsome, 2015). • Most of the reviewed studies investigated teachers' static PCK. About one third of them utilised one single instrument to determine the teacher's/teachers' PCK. • Majority focused on investigating one variant of teachers' PCK (i.e., either static PCK or dynamic PCK). Only three studies designed instrument to collect data of both PCK variants. Implications & Significance: This study identified commonalities and differences among the diverse methodologies for investigating science teachers' PCK. A better

understanding of the different approaches would allow readers to more critically compare and contrast the findings of different studies and to make informed decisions on how they would investigate teacher's/ teachers' PCK to answer their research questions.

Back to programme

(S240) ESTABLISHING AND REALISING A VISION FOR PCK RESEARCH IN SCIENCE EDUCATION

Symposium Paper 3

Representing the complexity of PCK in action

Amanda BERRY, *Monash University*
Alicia ALONZO, *Michigan State University*
Pernilla NILSSON, Halmstad University

Abstract

Introduction & Study goals: Since its introduction into the research literature 30 years ago, pedagogical content knowledge (PCK; Shulman, 1986, 1987) has become widely recognised as a distinctive component of teachers' professional expertise. Yet, there exists considerable diversity in the ways that researchers have conceptualised PCK. We identify two main views within this diversity: conceptualisations of PCK as a static form of teacher knowledge, and conceptualisations of PCK as more dynamic. Although much attention has been devoted to the static view (i.e., through attempts to 'measure' teachers' PCK), the dynamic view is critical for understanding how teachers confront "the challenge of teaching particular subjects to particular learners in specific settings" (Shulman, 2015, p. 9). In this paper, we review efforts to capture – and to retain the complexity of – PCK from the dynamic perspective. Methodology: We identify three main approaches to capturing PCK from a dynamic perspective. The first approach focuses on efforts to elicit teachers' Practice Pedagogical Content Knowledge (pPCK), that is, what teachers actually do in their practice in specific classroom contexts while teaching particular content to particular students. Methods employed in this approach (often in combination) include classroom observations, interviews, video-stimulated recall, and specifically-designed tools, e.g., Content Representations (CoRes) and PaPeRs (Pedagogical and Professional experience Repertoires). The second approach also focuses on teachers' existing practice (i.e., their pPCK), but highlights the pedagogical reasoning that occurs while planning and reflecting (rather than during instruction). Methods include asking teachers to think-aloud during lesson planning and post-lesson reflections, and use of video fragments. Finally, the third approach attempts to elicit teachers' in-the-moment reasoning in specific classroom situations that are simulated outside of the classroom. This combines pPCK with Individual Pedagogical Content Knowledge (iPCK), the accumulated repository of pedagogical content knowledge and skills from within the teacher's own experiences along with the contributions of others. Methods in this category attempt to approximate aspects of teachers' work in real classrooms through, for example, asking teachers to respond in authentic ways (e.g., responding directly to a "student") and presenting situations using realistic materials to prompt responses, such as video and even live actors. Findings & Discussion: There is a tension between studying a complicated phenomenon in situ, with all of the surrounding complexity of its environment (approaches 1 & 2), and isolating the phenomenon in a less authentic environment in order to deepen our understanding of the phenomenon itself (approach 3). In this paper, we describe the affordances and constraints of these approaches to capturing teachers' PCK. Implications & Significance: This work is crucial to supporting teachers' practice throughout their careers and, in turn mediating student outcomes. By elaborating the concept of "PCK in action" as teachers'

application of PCK during the pedagogical cycle (planning, enacting, reflecting) and contextualizing this form of PCK within the layers of an individual teacher's PCK and the greater collective of PCK, we hope to bring greater clarity to the nature of teachers' professional knowledge, highlighting a continuum from private to public components of PCK.

Back to programme

(S263) TEACHING AND LEARNING SCIENCE THROUGH THE LANGUAGE LENS (PART 1)

Symposium Integrative Summary
This symposium brings together a team of researchers and teachers who have worked collaboratively to address their learner needs through the lens of language and literacy in science teaching. The team co-developed teaching approaches and strategies to support students in deepening their understanding and use of scientific language. The team works on the assumption that learning the language of science is constitutive of learning science. By participating simultaneously in classroom activities and conversations around language, describing observations and developing conceptual understanding, students begin to appropriate the language of science. Individual teachers undertook iterative cycles of an inquiry process supported by researchers from the National Institute of Education and the English Language Institute of Singapore. Each cycle of inquiry typically begins with an evidence-based session involving a discussion of teacher-curated students' writings to identify students' language-related challenges and possible solutions to address these challenges between the teacher and researchers. The teachers took ownership in co-designing follow-up interventions to be situated and trialed in subsequent science lessons. Each inquiry cycle concluded with a post-lesson reflective session to discuss the outcomes of the interventions. The cycle was then repeated with a new set of student artifacts that provide fresh insights into students' language needs. Such an evidence-based approach ensures that the classroom interventions proposed are contingent on students' needs and relevant to the curriculum. The inquiry approach also ensures that teachers engage their current ideas alongside co-designed innovations, thus affording concurrent professional development and practical pedagogical innovations that have the potential to improve student outcomes. In this 2-part series symposium, the researchers and teachers will share their experiences and insights from the inquiry process. For this part 1 symposium, the researchers begin with a presentation to outline the rationales and goals of the inquiry process. Two primary science teachers will in turn share a range of teaching approaches and strategies they have developed as well as the outcomes and challenges they encountered in the process of implementing them. A Part 2 symposium (submitted as a separate proposal) continues with two more presentations and will be concluded by our invited discussant, Associate Professor Tan Aik Ling, who will synthesize the outcomes of the five presentations and provide insights for moving the research forward.

Back to programme

(S263) TEACHING AND LEARNING SCIENCE THROUGH THE LANGUAGE LENS (PART 1)

Symposium Paper 1

Adopting Teacher Language Awareness as a lens to inform a professional development inquiry process to infuse language support for science learning

Lay Hoon SEAH, *National Institute of Education, Nanyang Technological University, Singapore*
Jonathon ADAMS, *Ministry of Education, Singapore*

Abstract
Like the language of other disciplines, scientific language, with its own unique lexicon, grammar and semantics, has evolved to meet its particular disciplinary requirements (Halliday & Martin, 1993). The unique features of the scientific language, and their concomitant affordances and constraints, underscore the important role that language plays in both science and science learning. From this position, teachers of science must also be teachers of the language of science. Research studies over the recent decades have focused primarily on developing and testing the efficacy of teaching strategies and practices that support learners' language and literacy skills in science. However, there has been limited research and reports on what support and knowledge are required by teachers for them to fully leverage on these strategies to achieve the potential learning gains that such strategies have been shown to accomplish. In particular, we would like to unpack the knowledge and skills that science teachers would need in order to conduct focused oral interactions with students in order to support science writing. Teacher Language Awareness (TLA) is a particularly useful notion for the research purpose of this study. Used mainly in second language teaching research, TLA denotes 'the knowledge that teachers have of the underlying systems of the language that enables them to teach effectively' (Thornbury, 1997, p. x). In this project, we adopted TLA as a notion to both inform and examine the inquiry process we have undertaken in collaboration with our partnering teachers. Specifically, we examine what aspects of TLA are invoked during the inquiry process and how these aspects shape the design and enactments of the teachers' pedagogical innovations. Our notion of TLA encompasses the various aspects of language demands of science that have been unpacked and theorised by linguists, literacy researchers and more recently, science education researchers (e.g., Halliday, 2004, Fang, 2015; Seah et al., 2016). These aspects include school science genres, lexicogrammatical features of scientific language, and topic-specific students' language errors. In this presentation, we will share our rationales for using TLA as our guiding principle in facilitating the inquiry sessions as well as its potential as an analytical lens in our examination of the professional development that our partnering teachers embarked on with us. Through this research process, we seek to better understand the pedagogical principles and strategies needed to support students in their understanding and use of scientific language.

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Explanations. Research in Science Education, 46(3), 413-437. doi: 10.1007/s11165-015-9464-z Thornbury, S. (1997). About language. Cambridge: Cambridge University Press.

Back to programme

(S263) TEACHING AND LEARNING SCIENCE THROUGH THE LANGUAGE LENS (PART 1)

Symposium Paper 2
Developing Science Literacy in primary classrooms

Azlinda ABD AZIZ, *Pioneer Primary School*

Abstract
This study presents and examines classroom practices that can be conducted in Science classrooms to simultaneously improve students' English and Science literacy development. Three approaches, inspired by literature such as Fang, Lamme and Pringle (2010), Gibbons (2002, 2009), Rose and Martin (2012), were conducted with a group of Primary 5 students to foster their use of scientific language. These include discussing the use of specific nouns for pronouns which are loosely used in Science writing, matching noun and verb in the Science context as well as using a scientific writing strategy, namely SPC (Scientific Ideas – Cue Prompts – Closure) to guide students in their thinking processes to construct coherent and precise sentences in scientific writing. The different approaches emphasized various aspects of the language of science. The first two approaches brought students' attention to the linguistic resources that constituted the scientific language as well as the need for their precision and accuracy. By contrast, the third approach highlighted the structural components of science genres. These approaches stimulated increased communication in science among students, thereby engaging them in their language development and understanding (Pearson, Moje and Greenleaf, 2010). To analyse the impact these approaches had on their scientific writing, I examined students work for their quality, specifically the way students adopted the language practices emphasized by these approaches. These approaches were found to be effective in helping students develop skills in writing coherent sentences in their scientific writing, on the condition that students have developed their content understanding well. Specifically, students were motivated to ensure their responses were precise and accurate. This helped to bridge both Science and English language development. One insight gained is the need for these approaches to be well-integrated alongside content development as students. In conclusion, such language support can positively help students to improve their scientific writing and support their development as a self-directed learner. Insights on the affordances and limitations of the various approaches will also be shared during the presentation. Finally, potential improvements that can be made to the existing approaches will also be discussed.

Reference: Fang, Z., H., Lamme, L. L., & Pringle, R. M. (2010). Language and literacy in inquiry-based science classrooms, grades 3-8. Thousand Oaks, California: Corwin Press. Gibbons, P. (2002). Scaffolding language, scaffolding learning: Teaching second language learners in the mainstream classroom. Portsmouth, N.H.: Heinemann. Gibbons, P. (2009). English learners, academic literacy, and thinking: Learning in the challenge zone. Portsmouth, N. H.: Heinemann. Pearson D., Moje E., Greenleaf C. (2010). Literacy and Science: Each in the Service of the Other, Science, 328 (5977), 459-463. DOI: 10.1126/science.1182595 Rose, D., & Martin, J. R. (2012). Learning to write, reading to learn: Genre, knowledge and pedagogy in the Sydney school. Sheffield (UK) and Bristol (USA): Equinox Publishing Ltd.

Back to programme

(S263) TEACHING AND LEARNING SCIENCE THROUGH THE LANGUAGE LENS (PART 1)

Symposium Paper 3

Investigating the use of word cards in the teaching of Science

Nurhuda AMIN, *West Grove Primary School*

Abstract

Language demands on science students, even those as young as the primary levels, can be remarkably high (Seah and Yore, 2017). Without paying sufficient attention to these demands, students' science learning can be impeded. In fact, Wellington and Osborne (2001), went as far as to argue that for many students 'the greatest obstacle in learning science—and also the most important achievement—is to learn its language' (p. 3). In this study, magnetic word cards were piloted and its effectiveness in supporting students' sense-making and use of language of the water cycle was examined in comparison to previous teaching method that favoured the use of frontal teaching. Word cards, used as visual cues, were created for the processes and states of water in each stage in the cycle. During the lesson, students annotated the water cycle drawing on the whiteboard and placed the cards in the respective position. Supported by teacher's active questioning, students were engaged in reviewing, negotiating and moving the cards. Through this process of interactions, students actively participated in meaning-making that is important for promoting deep understanding of science (Kelly, 2007). The use of these word cards provided students with a model for how the words are used appropriately to describe the water cycle. The lesson was consolidated with an individual writing section where the completed cycle on the whiteboard formed the basis of a writing scaffold. The students' writing process was further supported by a series of prompts that sought to guide students through the thinking process and ensured that students provided sufficient information to fulfil the requirements of the writing task. Through the combination of the diagrammatic representation of the water cycle, word cards and prompts, the majority of the students were able to complete the writing task successfully. For this presentation, I will share the affordances and limitations in using this visual aid to facilitate whole-class discussion and students' writing. Impacts and implications of this pedagogical tool on students' engagement as well as comprehension and retention of the water cycle will also be discussed using data taken from the video recording of the lesson, student artifacts, and post-lesson reflection session with the researchers. Finally, further potential enhancements to the use of this tool will also be shared.

References: Kelly, G. J. (2007). Discourse in science classrooms. In S. K. Abell & N. G. Lederman (Eds.), Handbook of research in science education (pp. 443–469). Mahwah, NJ: Lawrence Erlbaum Associates. Seah, L. H., & Yore, L. D. (2017). The roles of teachers' science talk in revealing language demands within diverse elementary school classrooms: a study of teaching heat and temperature in Singapore. International Journal of Science Education, 39(2), 135-157. doi:10.1080/09500693.2016.1270477 Wellington, J. J., & Osborne, J. (2001). Language and Literacy in Science Education. Philadelphia: Open University.

Back to programme

(S266) TEACHING AND LEARNING SCIENCE THROUGH THE LANGUAGE LENS (PART 2)

Discussant: A/P Aik Ling TAN, *National Institute of Education, Nanyang Technological University, Singapore*

Symposium Integrative Summary
This symposium brings together a team of researchers and teachers who have worked collaboratively to address their learner needs through the lens of language and literacy in science teaching. The team co-developed teaching approaches and strategies to support students in deepening their understanding and use of scientific language. The team works on the assumption that learning the language of science is constitutive of learning science. Individual teachers undertook iterative cycles of an inquiry process supported by researchers from the National Institute of Education and the English Language Institute of Singapore. Each cycle of inquiry typically begins with an evidence-based session involving a discussion of teacher-curated students' writings to identify students' language-related challenges and possible solutions to address these challenges between the teacher and researchers. The teachers took ownership in co-designing follow-up interventions to be situated and trialled in subsequent science lessons. Each inquiry cycle concluded with a post-lesson reflective session to discuss the outcomes of the interventions. The cycle was then repeated with a new set of student artifacts that provide fresh insights into students' language needs. Such an evidence-based approach ensures that the interventions proposed are contingent on students' needs and relevant to the curriculum.
The inquiry approach also ensures that teachers engage their current ideas alongside co-designed innovations, thus affording concurrent professional development and practical pedagogical innovations that have the potential to improve student outcomes. In this 2-part series symposium, the researchers and teachers will share their experiences and insights from the inquiry process. In the Part 1 symposium (submitted separately), the researchers begin with the rationales and goals of the inquiry process. Two primary science teachers will in turn share a range of teaching approaches and strategies they have developed as well as the outcomes and challenges they encountered in the process of implementing them. This Part 2 symposium continues with another presentation by a secondary science teacher, who will also share her instructional approach and research outcomes. The last presentation by the researchers will provide a different perspective on the role of teachers, specifically their classroom talk, in promoting students' understanding and use of scientific language. Finally, our discussant, Associate Professor Tan Aik Ling, will synthesise the outcomes of the five presentations (including those from the part 1 Symposium) and present her insights that will more the research forward.

Back to programme

(S266) TEACHING AND LEARNING SCIENCE THROUGH THE LANGUAGE LENS (PART 2)

Symposium Paper 1

Support for helping secondary school students in constructing logical and concise writings in Science

Swee Leng YEO-TAN, *Ping Yi Secondary School*

Abstract

This study was designed in collaboration with researchers to create students' awareness on the purposeful use of language to communicate science ideas in the classroom as well as to build their confidence in using scientific language to construct scientific explanations proficiently. The importance of learning to use the language of science is increasingly recognized not just for its fundamental role in acquiring conceptual understanding (Wellington and Osborne, 2001) but also for engaging in scientific practices which can also be highly language intensive (Lee, Quinn and Valdés, 2013). As part of the inquiry process that I undertook with the researchers, I have progressively revised over multiple inquiry cycles a crafting and writing template that the Lower Secondary Science teachers have developed initially. In this presentation, I will share how the template has evolved over time and what has led to the changes made to the template. Changes made to the template were inspired by literatures such as Fang, Lamme and Pringle (2010), Gibbons (2002, 2009), Rose and Martin (2012). The evolution process of the template was informed by the analysis of the students' writings that was discussed during the pre-lesson inquiry sessions and the reflective dialogue during the post-lesson inquiry sessions. From the students' language challenges identified from their written work, new scaffolds were developed and included into the template to support their writing in a new topic. These scaffolds were piloted and examined for their ease of use by students and their effectiveness in supporting their writing process. These scaffolds were adjusted subsequently to better meet the needs of the students. This presentation thus seeks to provide an empirical trail of the process undertaken to systematically revise the writing template. Affordances and limitations of the writing template as well as implications for science teaching in general will also be discussed in the presentation.

References: Fang, Z., H., Lamme, L. L., & Pringle, R. M. (2010). Language and literacy in inquiry-based science classrooms, grades 3-8. Thousand Oaks, California: Corwin Press. Gibbons, P. (2002). Scaffolding language, scaffolding learning: Teaching second language learners in the mainstream classroom. Portsmouth, N.H.: Heinemann. Gibbons, P. (2009). English learners, academic literacy, and thinking: Learning in the challenge zone. Portsmouth, N. H.: Heinemann. Lee, O., Quinn, H., & Valdés, G. (2013). Science and Language for English Language Learners in Relation to Next Generation Science Standards and with Implications for Common Core State Standards for English Language Arts and Mathematics. Educational Researcher, 42(4), 223-233. doi:10.3102/0013189x13480524 Rose, D., & Martin, J. R. (2012). Learning to write, reading to learn: Genre, knowledge and pedagogy in the Sydney school. Sheffield (UK) and Bristol (USA): Equinox Publishing Ltd. Wellington, J. J., & Osborne, J. (2001). Language and Literacy in Science Education. Philadelphia: Open University.

Back to programme

(S266) TEACHING AND LEARNING SCIENCE THROUGH THE LANGUAGE LENS (PART 2)

Symposium Paper 2

The role of classroom discourse in promoting students' competency in language use in science

Lay Hoon SEAH, *National Institute of Education, Nanyang Technological University, Singapore*
Pavithra RAJA, *National Institute of Education, Nanyang Technological University, Singapore*
Zhao Xiong LIM, *National Institute of Education, Nanyang Technological University, Singapore*

Abstract

While effective language scaffolds, activities and tasks are important to promote the effective understanding and use of scientific language, classroom discourse serves an equally crucial role. After all, the latter is a significant means by which teacher and students engage in meaning-making and promoting shared understanding (Kelly, 2014). Traditionally, analysis of science classroom discourse has focused mainly on the role of teachers' talk in developing students' content knowledge and thinking skills (see for example, Lemke, 1990, Mortimer and Scott, 2000). Relatively less attention has been given to how it can support students in their use of language. This study explores the ways in which the partnering teachers foreground particular aspects of language and bring them to the attention of students. Using the lens of both socioconstructivist and sociosemiotic perspectives of learning (Seah, Clarke and Hart, 2014), transcripts of lessons from three teachers were examined for instances during which the teachers highlighted particular aspects of language. These instances were then subjected to analysis using a previously developed discourse analytical framework developed for the same purpose, the Addressing Language Demands of Science framework (Seah & Yore, 2017). New analytical categories were identified in the process, inspired by another study conducted by Tang (2017) that examined teachers' use of metadiscourse. Through the classification of these discursive strategies, this study sought to understand how teacher talk can support students in learning the language of science. Overall, three broad classifications of the analytical categories can be identified: discursive strategies focusing on specific instances of language use, discursive strategies focusing on a general aspect of language, and metadiscoursal talk for promoting language use and awareness. Implications for research, teaching and professional development will also be discussed.

References: Kelly, G. J. (2014). Discourse practices in science teaching and learning. In N. G. Lederman & S. K. Abell (Eds.), Handbook of research on science education (Vol. 2, pp. 321–336). New York, NY:Routledge. Lemke, J. L. (1990). Talking Science: Language, Learning, and Values. Norwood, N.J.: Ablex Pub. Corp. Mortimer, E. F., & Scott, P. (2000). Analysing discourse in the science classroom. In R. Millar, J. Leach, & J. Osborne (Eds.), Improving Science Education: The Contribution of Research (pp. 126-142). Buckingham: Open University Press. Seah, L. H., Clarke, D. J., & Hart, C. E. (2014). Understanding the Language Demands on Science Students from an Integrated Science and Language Perspective. International Journal of Science Education, 36(6), 952-973. doi:10.1080/09500693.2013.832003 Seah, L. H., & Yore, L. D. (2017). The roles of teachers' science talk in revealing language demands within diverse elementary school classrooms: a study of teaching heat and temperature in Singapore. International Journal of Science Education, 39(2), 135-157. doi:10.1080/0

9500693.2016.1270477 Tang, K.-S. (2017). Analyzing Teachers' Use of Metadiscourse: The Missing Element in Classroom Discourse Analysis. Science Education, 101(4), 548-583. doi:10.1002/sce.21275

(S305) ENHANCING STUDENTS' CONTENT LEARNING THROUGH MULTI-MODAL MEANING-MAKING IN PRIMARY SCIENCE

Symposium Integrative Summary

This symposium comprises papers drawing on school-based research from Singapore mainstream schools in collaboration with the English Language Institute of Singapore and the Academy of Singapore Teachers. The interest centres on enhancing primary science students' conceptual understanding through multimodal meaning-making practices. In science education research, representations are seen as 'artifacts that symbolise an idea or concept in science and can take the form of written texts, analogies, diagrams, graphs, and simulations' (Tang, 2016, p.2072). These artifacts involve the integration of multimodal semiotic systems (or modalities) for meaning making (Kress et al., 2001; Lemke, 1998) for specific purposes in various contexts. There is a growing recognition of the significance of visual modes in science knowledge production, and interpreting and constructing science texts (Prain & Hand, 2016, p.4). Indeed, the use of representations can be 'considered as a crucial epistemic practice by the scientific community' (Yeo & Gilbert, 2017, p.255). In the local context, among the assessment objectives identified at the primary science level are for students 'to demonstrate knowledge and understanding of scientific facts, concepts and principles' and 'communicating' is viewed as one of the 'process skills' in interpreting information (including pictorial, tabular and graphical) (SEAB, 2017,p. 1). The first two papers showcase teachers' pedagogical efforts of multimodality for specific purposes. The third paper discusses some implications for teacher professional learning with regard to facilitating understanding of the multimodal pedagogical practices enacted in the other two papers. Collectively, the papers build on each other thematically and reinforce each other through a unifying focus in attempting to support students' content learning through 'the purposeful integration of semiotic resources' (Vaish & Towndrow, 2010, p. 321) where the various modes interplay with each other through how they 'are combined and designed to make meaning' (Baldry, 2001; Kress & van Leeuwen, 2001) for different purposes. Active student engagement facilitated by concrete scaffolds in various modalities and resources are explored through teachers' skilful design of learning tasks in specific contexts. This panel seeks to raise awareness and understanding of the 'power of representational tools as modes for communicating understanding' and 'for providing individuals a means for personal negotiation of meaning' (McDermott, 2016, p.240) through the learning opportunities available. At the same time, it seeks to highlight challenges encountered in contextualizing multimodality in the Primary Science classroom and examines how these could be addressed.

Back to programme

(S305) ENHANCING STUDENTS' CONTENT LEARNING THROUGH MULTI-MODAL MEANING-MAKING IN PRIMARY SCIENCE

Symposium Paper 1

Supporting students' conceptual understanding through the use of student-created notebooks in primary science

Caroline HO, *Ministry of Education, Singapore*
Noorhafidzah SHAFFI, *Ang Mo Kio Primary School*
Amy TAN, *Ang Mo Kio Primary School*
Choo Lat WONG, *Ang Mo Kio Primary School*

Abstract

Primary Science teachers were keen to help their upper primary students enhance their conceptual understanding through the children's creation of their own science notebooks (Shepardson & Britsch, 2000, 2001) incorporating text with diagrams, drawings and/or tables. Grounded in Vygotskyan (1978) constructivist underpinnings with students central to the learning process, the emphasis is on creating opportunities for students to conceptualize their understandings in science (Doris, 1991; Hargrove & Nesbit, 2003; Thier, 2002) through their own lens of experience (Shepardson, 1997) and in ways valued by scientists (Shavelson, 2001). Teachers of Grades 5 and 6 students explored how they could make their students' thinking visible (Ritchhart, Church & Morrison, 2011) through students constructing their own artifacts to represent their understanding of Science concepts related to Water cycle, Cells and Forces. Learners' creative capacity in using semiotic resources to construct meaningful knowledge through multimodal representations (Ho et al, 2010) is foregrounded as a strategy to help them learn science (Fellows, 1994; Shepardson & Britsch, 1997). Through the school's collaboration with the English Language Institute of Singapore (ELIS), a framework was developed for monitoring and evaluating students' artifacts to determine the extent to which students' conceptual and procedural knowledge were made explicit, and how they organise their ideas in a meaningful way. The extent to which students' accurate use of specific content vocabulary was evident in expressing their conceptual understanding, and in making clear the links or relationships between concepts was also of interest. Data sources included students' artifacts, teachers' instructional resources, teachers' reflections and students' feedback from focus group discussions. Teachers' and students' perspectives on their personal gains and difficulties encountered are presented. Teachers benefited from having opportunities to assess pupils' understanding of concepts, identifying misconceptions, reinforcing content recall and consolidation, providing strategic feedback for further refinement of details and stretching high progress students to express conceptual understanding through creative expressions of notebooking. Students' gains ranged from understanding and addressing task demands, content recall and reinforcement, specific skills pertaining to writing including clarity in scientific explanation, and precision in scientific language use. The findings further highlighted the need for differentiated support for high and low progress students with varying degrees of scaffolding and specific measures to address on-the-ground realities and contextual classroom constraints. Pedagogical implications are discussed with a view to helping teachers provide viable opportunities for students to acquire 'scientific ways of being and thinking' and to balance the syllabus demand of breadth of content

coverage with depth in enhancing conceptual understanding. The paper further discusses how the integration of notebooking aligned with the syllabus requirement can be used by teachers and students meaningfully in primary science classrooms in our local school context. This paper argues for the place of notebooking as an instantiation of multimodality to enable students to access, internalise, meaningfully engage with and creatively construct their understanding of scientific conceptual content.

Back to programme

(S305) ENHANCING STUDENTS' CONTENT LEARNING THROUGH MULTI-MODAL MEANING-MAKING IN PRIMARY SCIENCE

Symposium Paper 2

Using of multimodal representations for differentiated instruction

Sumathi MANICKAM, *Park View Primary School*
Yong Ngee KANG, *Park View Primary School*

Abstract

Scientific knowledge is constructed and communicated through a variety of representations. The ability to interpret, transform, and produce representations, is a key component in construction of scientific knowledge. This can be achieved in the science classroom through application of Differentiated Instruction (DI) strategies because they provide students with multiple and flexible means of representation, expression, and options for engagement (Gregory & Chapman, 2007; Hall, 2012; Rose & Meyer, 2004; Tomlinson, 2004). This presentation provides an overview of a study that examines how DI strategies can be used to enhance conceptual understanding of Primary Four students in a primary school in Singapore. The key findings, challenges faced, and reflections by teachers who implemented the lessons in their own classrooms will be shared. This study involved four classes of Primary four students which took place over one year. Each class had at least 35 students of diverse profiles with varying interests and strengths. The science teachers involved in the study are members of a Professional Learning Team (PLT). The aim of the PLT was to help students of different learning profiles to learn, understand and demonstrate their understanding of science concepts through multi-modal meaning-making practices enacted in DI lessons where the processes and products of learning were differentiated. During differentiated learning in process, students were exposed to the different representations of the same concept using learning centres strategy. Learning materials were examined and redesigned to incorporate multiple modes of representations and options for different modes of expressions by students. This supports meaning-making process among students of all learning profiles. For the topic on Life Cycles, the teachers designed learning experiences intentionally incorporating multi-modal representations to engage students. Students needed to interpret information from a variety of representations (including pictures/ diagrams, mindmaps and simulations) to enhance conceptual change. For the topic on Matter and Heat, the teachers designed evaluative tasks which are differentiated. Students were provided with opportunities to select from a choice board of tasks allowing them to demonstrate their knowledge and understanding of scientific concepts through different modes of expression. Student's products were uploaded onto an online class social learning wall for peer evaluation. Both quantitative and qualitative data were collected and analysed. Data comprised choices of products, students' products of learning, learning outcomes and structured reflections from teachers who implemented the lessons. The project enabled teachers to gain insight into students' learning profiles and their alternative conceptions in learning. Data will be utilised when crafting future lessons. As students were young, it was evident from their products they were still exploring their individualised modes of expression. Students reflected that they understood the concepts better and took pride in their independent learning since products were not

stipulated by the teachers. Students became more intrinsically motivated to learn science due to their increased engagement.

Back to programme

(S305) ENHANCING STUDENT, CONTENT LEARNING THROUGH MULTI-MODAL MEANING-MAKING IN PRIMARY SCIENCE

Symposium Paper 3

Supporting teachers' use of multi-modal meaning-making

Anne WONG, *Academy of Singapore Teachers, Ministry of Education*
Lai Har Judy LEE, *Academy of Singapore Teachers, Ministry of Education*

Abstract

In the teaching and learning of primary science, teachers engage students in scientific practices by inducting them in the use of the languages of science when constructing conceptual understanding. The languages of science include linguistic, symbolic and visual representations (Lemke, 1998). As teachers engage students in the learning of science through multiple representations, they also need to help students translate between different representations and integrate them during the meaning-making process (Ainsworth, 1999). Science learning involves conceptual change which entails the modification of one's mental models about how the world works (Vosniadou, 1994). Providing students with opportunities to construct and critically revise their models is hence a means for helping them to build conceptual understanding. An example of a student model-based reasoning approach to science teaching and learning is the representation construction pedagogy (Tytler, Prain, Hubber, & Waldrip, 2013; Tytler & Hubber, 2016). The principles undergirding this approach are: (a) teaching sequences need to be based on sequences of representational challenges, (b) representations should be explicitly discussed, (c) meaningful learning activities need to provide strong perceptual contexts and afford student engagement and agency, and (d) students should be provided with opportunities to generate and interpret representations (Tytler & Hubber, 2016). There are challenges in the use of such a teaching and learning approach before full benefits may be reaped. Research has shown that students may experience information overload when presented with multiple representations (Clark & Mayer, 2011). They may also struggle with making connections between phenomena and the representations of phenomena, as well as the connections among the different representations used (Kozma, 2003). The use of such student model-based reasoning approaches also entail the development of meta-representational competencies in students to enable them to participate in scaffolded discussions on the critique of representations (Tytler & Hubber, 2016). In order to support the development of students' meta-representational competencies, it is necessary to develop teachers' meta-representational competencies as well. This aspect was discussed by Waldrip and Prain (2013) who noted the need to clarify teachers' understanding of the "form, function and purpose of representational work in the classroom" (p. 18) as well as teachers' perception that the representational approach had made new demands on their teaching skills and knowledge. Using the principles underlying the representation construction pedagogy (Tytler & Hubber, 2016) as a frame, the presenters will discuss implications on the design of professional learning experiences for raising awareness and building competencies on the use of representations in primary science classrooms in Singapore. Examples of how some of these principles were put into practice will be shared. Discussion will also include considerations given to on-the-ground realities faced by classroom teachers and how these could be addressed to support students' multimodal meaning-making more effectively.

Back to programme

(W172) RASCH MEASUREMENT FOR IN-CLASS SCIENCE ASSESSMENTS

Vahid ARYADOUST, *National Institute of Education, Nanyang Technological University, Singapore*

Abstract

One of the main steps in developing reliable tests for in-class assessments is to ascertain their psychometric reliability. This stage is often not carried out with much rigour because teachers and practitioners would view content-based evidence for validity as sufficient. This workshop aims to address this gap by introducing the Rasch model and its application to science classroom assessments. The Rasch model is a probabilistic model which was developed by Dane mathematician and statistician, Georg Rasch. The model is used to determine the chances of persons (e.g., students) with specified ability levels to answer certain test items with known difficulty levels. The Rasch model has also been extended to model polytomous items which are commonly used in surveys and questionnaires. In this workshop, the underlying principles of the Rasch model will be explained in an accessible language to teachers and practitioners, and participants will learn to use the software package WINSTEPS to output useful psychometric information regarding their tests. The information outputted will be used to examine the degree to which students' performance can be used to generate reliable measures of their abilities and to examine if the test items engage the desirable attribute(s) and knowledge(s). The following topics will be covered in the workshop: ♣ Item difficulty / endorsability and person ability: These are the two parameters of the Rasch model which are estimated using maximum likelihood method of parameter estimation and scaled onto log-odd units (logits). The advantage of logit scales is that one can directly compare item difficulty and person ability and estimate the probability for persons to answer any items accurately. ♣ Item-person map: It is a visual representation of item difficulty / endorsability and person ability, standard deviations, and mean indices per each. ♣ Fit statistics: Quality control statistics indicating whether there are any erratic patterns in test responses. Several fit statistics will be discussed and examples will be provided to facilitate their interpretation. ♣ Reliability, separation, and error of measurement: These useful statistics show whether the test has been able to discriminate between students / people of different ability levels. (It will be briefly discussed that there is no need to add a discrimination parameter to generate a two-parameter logistic item response theory and the Rasch model is able to inform the test developer about the discrimination of the items). ♣ The principle of unidimensionality: One important underlying assumption of Rasch measurement is psychometric unidimensionality. A useful method to investigate this assumption will be introduced and the participants will be given enough time to do hands-on practices. It is expected that after the workshop the participants will be able to apply their knowledge and experience with the Rasch model to their in-class and/or large-scale language tests and examine the validity of students' scores. Anyone who is interested in assessment and measurement is welcome.

Back to programme

(W184) A MODELLING APPROACH TO THE TEACHING OF CHEMISTRY USING WHITEBOARDING

Li Kheang KOO, *Cedar Girls' Secondary School*
Yan Li TAN, *Victoria School*
Julianah JOHAR, *Jurong Secondary School*

Abstract

(A) Significance & Objectives The learning of abstract concepts in chemistry presents a challenge to many students all over the world. At the high school level in many countries, students generally struggle with the grasp of some of the fundamental concepts which form the foundation for the mastery of more advanced concepts in tertiary institutions. (Carter, C.S. & Brickhouse, M.W., 1989; Nakhleh, M.B. , 1992 and Kamisah,O. & Nur, S., 2013). Students also generally hold alternative conceptions, and often demonstrate a low level of engagement in chemistry lessons due to the abstract nature of the subject. Research has also shown that direct instruction generally does not help to address the issue of alternative conceptions (Harrison & Treagust, 2002 and Fischler & Reiners, 2006). The acquisition of a good understanding of fundamental concepts in chemistry requires students to do a versatile translation between macroscopic and microscopic modes of representing particles (Bradley & Brand, 1985; Treagust, et al, 2003). This is an important skill that needs guidance before students can use it effectively to explain the link between properties of matter and behaviour of particles. Classroom teaching should incorporate strategies which makes students' thinking visible to teachers so that misconceptions can be addressed and clarified. (B) Methodology: Whiteboarding a strategy used to support the pedagogy involved in Modelling Instruction* has been shown to effectively build students' understanding and help identify misconceptions (Dukerich, L., 2015). It gives students a platform to engage in meaningful conversation and presents them the opportunity to represent their mental models pictorially, symbolically, graphically and mathematically. Lessons conducted using whiteboarding enables teachers to "peek" into the minds of their students to find out what they really understand. (C) Findings and Discussion: Teachers from the Chemistry Department in Victoria School and Cedar Girls' Secondary School have been making use of whiteboarding to teach selected chemistry topics to the Year 3 to 4 (15 to 16-year-old) students since 2015. Evidence collected from the information presented in the whiteboards by the students showed that whiteboarding is indeed a useful strategy capable of eliciting misconceptions. Due to the interactive nature of the strategy used, students are also kept engaged in the lesson as reported by teachers who sat in the lesson as critical friends. In this workshop, the teachers from these two schools will be sharing how this strategy can be incorporated into classroom lessons through presentations and videos of actual lessons. This includes hands on inquiry based laboratory activities that can be designed to spark off the discussion and a group-based discourse to model "whiteboarding in action". (D) Implications of the Study: By showcasing how traditional didactic lessons can be reconfigured to include whiteboarding strategies to elicit and address misconceptions and engage students in scientific discourse, the presenters hope that more teachers will be encouraged to try out this strategy in their own classrooms to make science lessons more interesting and fulfilling for their own students.

Back to programme

(W241) INQUIRY IN SCIENCE: FUN WITH TOYS

Su Sze KONG, *Queenstown Primary School*
Soon Shan TAN, *Queenstown Primary School*
Lay See LIM, *Queenstown Primary School*
Yen Peng TAN, *Queenstown Primary School*

Abstract

Understanding of Science concepts is best developed by enabling a learning environment which provides students with opportunities to explore playing with the toys and engage in group discussions and challenge each other's ideas. Toys are inherently motivational and interactive. They make abstract concepts concrete and relevant to students' lives and demonstrate Science in the real world vs Science in the Science laboratory. 5 E (Engage, Explore, Explain, Elaborate, and Evaluate) instructional model, productive questioning and students' discussions, which are constructivist approaches are used to develop the understanding of Science concepts while playing with the toys. Students learn when they are actively thinking. To make sure thinking is structured, we need to create learning experience that provides opportunities for students to construct knowledge. This purposeful play with toys helps to bring out the playful, investigative side of all students while developing process skills, attitudes and understanding of the Science concepts. Teachers' questioning encourages greater student participation, elicits students' thinking and facilitates the understanding of the concepts. Teacher can elicit students' prior knowledge and promote curiosity through the use of toys and attention –focusing question at the Engage phase. The Explore phase focuses students' attention on exploration experiences when playing with toys and provides them with opportunities to demonstrate their conceptual understanding and process skills. Problem-posing and action questions are used at this phase. Teachers could guide students towards a deeper understanding of concepts through reasoning questions at the Explain phase. Through the elaborate phrase, teacher can challenge and extend students' conceptual understanding and skills. The Evaluation phase encourages students to assess their understanding and provides opportunities for teachers to evaluate students' progress toward achieving the learning outcomes of playing with the toys. All productive questions could be used at the Elaboration and Evaluation phases. In using toys as learning tools, this would encourage dialogic interactions in which the students could justify their claims with appropriate evidence and reasoning. Teachers take on new roles in this Inquiry Science Classroom by guiding and supporting students to play an active role in the discussion to co-construct knowledge. Discussions are one of the best ways to help students learn to "talk science", construct understanding in a social context and help students to develop analytic and argumentation skills. To support these structured discussions, talk moves are used to frame questions and responses. They set students up to think, reason, expand their responses and involve a variety of students in the conversation, creating opportunities for all to participate in constructing knowledge collaboratively. In this workshop, we will share lesson ideas based on the 5 themes of Primary Science Syllabus: Diversity, Interaction, System, Cycles and Energy. Participants will have the hands on activities to discuss and design learning experiences for students to co-construct new knowledge using readily available toys, discussions and productive questioning at the different phrases of the 5E instructional model as the theoretical underpinnings and pedagogical approaches.

Back to programme

(W353) THE MIRROR HAS TWO FACES: USING "TEAM-BASED LEARNING" AS A PEDAGOGICAL APPROACH FROM BOTH THE INSTRUCTOR AND STUDENT'S PERSPECTIVES

Emmanuel TAN, *Lee Kong Chian School of Medicine, Nanyang Technological University, Singapore*
Preman RAJALINGAM, *Lee Kong Chian School of Medicine, Nanyang Technological University, Singapore*

Abstract
This workshop is designed for participants, who are keen to learn more about the team-based learning (TBL) pedagogical approach and its practicable application. TBL uses a student-centric and an active learning approach. TBL can be delivered effectively in both large (lecture size) and small classes (tutorial size). Like what is being alluded in the title of the movie The Mirror has Two Faces, this workshop aims to bring to the forefront a deeper appreciation of the TBL pedagogy by exploring it from both the instructor and student's perspectives. From an instructor's perspective, this workshop aims to outline the basic structure of a TBL session and the key pedagogical design considerations. From a student's perspective, this workshop aims to provide participants with an opportunity to experience a mini-TBL session, to gain further insights into the TBL pedagogy from the learner's perspective. In conclusion, science educators may not be new to the TBL pedagogy. However, in line with the theme of this conference, this workshop aims to examine the use of TBL with two "different lenses". The presentation of these two perspectives hopefully can aid participants in their "search" or "re-search" of science education. Workshop Outcomes: By the end of this workshop, the learner will be able to: 1. Identify the key elements of TBL 2. Explain the 4S criteria in writing a good quiz question 3. Identify actions that are/are not helpful in developing higher order thinking skills and collaboration between students. 4. Experience TBL as a learning approach.

Back to programme

(W361) GAME-BASED LEARNING FOR CHEMISTRY TOPICS: ATOMIC STRUCTURE AND CHEMICAL BONDING

Mea Fun CHONG, *Christ Church Secondary School*
Yun Yan Lynn TANG, *Christ Church Secondary School*
Qing Cong Eugene TEO*, Christ Church Secondary School*

Abstract
Atomic Structure and Chemical Bonding are abstract but fundamental topics in chemistry and many other topics make reference to them. Laying a strong foundation through reinforcing the concepts in the two topics is critical for greater ease of learning the subsequent topics. However, these two topics can be difficult to comprehend due to its abstract nature. In addition, research has shown that students' attitude towards learning is directly correlated to the knowledge that they acquire, and it impacts cognitive achievement. With the rise of gamification and research pointing towards games being an enabler to allow the learned content to be etched in the memory better than conventional method, Game-based Learning has been selected as the approach to improve the learning of Atomic Structure and Chemical Bonding and to introduce greater joy in learning. Instead of choosing a digital platform for the gameplay, physical cards were selected as the medium to encourage face-to- face interactions. This would allow people to pick up facial expressions, physical movements, and verbal tones during the gameplay, and these interactions would serve to develop the Socio-Emotional Competency of the students. In addition, by researching into game design, the game was developed and designed based on the three aspects of Mechanics (Rules), Dynamics (System), and the Aesthetics (Fun). The mechanics use the concepts involved in Atomic Structure and Chemical Bonding. The dynamics is enhanced through the use of visual representations such as cards, tokens, gameplay, and etc. The aesthetics of the game refers to the induction of emotional responses such as fellowship (group play), challenge (competition), and sensation (satisfaction). The game was introduced to the secondary two express and secondary three express students as part of their post-exam activity, and a pre-game test was conducted to assess their understanding of the topics at the start of the activity. Thereafter, the game was introduced to the students by phases, using the Kolb Learning Cycle as a framework for students to reflect upon their learning. Students were made to annotate their learning on a game booklet with questions to scaffold their learning along activity. At the end of the day, the students were tasked to complete a post-game test for the team to assess their learning from the game and compare the results with the pre-game test. In addition, a post-activity survey was conducted to assess their perceptions towards the activity. Through the workshop, more details will be shared with the participants to allow them to understand the context of the project. The results on the effects of the game in enhancing the learning of Atomic Structure and Chemical Bonding from the trial with the students will also be shared. Lastly, participants will be introduced to the game in phases and experience the gameplay.

Back to programme

(W362) DESIGN AND IMPLEMENTATION OF A TWO-TIER MULTIPLE CHOICE QUESTIONNAIRE TO ASSESS UNDERSTANDING OF EVOLUTION CONCEPTS

Kah Huat Robin SEOH, *NUS High School of Math and Science, Singapore*

Abstract

This study aims to clarify the understanding that learners have regarding evolution, particularly focusing on alternative conceptions (ACs) that grade 11-12 students in Singapore possess. This section of the study is the first part of the quantitative section of the study, comprising the design, development and administration of two sets of Two-Tier Multiple Choice (2TMC) Conceptual Inventories. The literature was consulted for resources developed by other research. Other resources included textbook examples, and past year GCE A' level examination questions. Past-year examiners' reports for the Singapore-Cambridge GCE A' level examinations were also reviewed for questions that have proven to be difficult for students, or where ACs were described directly. Some of the insights for the items or distractors were also derived from the author's previous encounters with ACs as an undergraduate student, and the experience gained from years of personal communications with students during individual, small group or class consultation sessions working on questions in evolution. The 24 multiple choice items for each of the instruments address ACs regarding the evidence and belief in evolution, or scenarios in which ACs could be reported. For most of the multiple choice items, an additional option (with blanks to clarify) was provided for students in case the available options, which were devised with reference to the literature, were unsatisfactory in capturing the conceptions of the students, allowing students to describe or explain their conceptions according to what and how they really think. In addition, for each of the multiple choice items, students were asked to describe their reasons for selecting specific responses, in order to formulate the second (reason) tier for the pilot study. Subsequently, students' actual descriptions were referred to in the setting of the options for the reason tier. Two sets of 20-item conceptual inventories, the Conceptual Inventory on Hominid Evolution (CIHE) and the Conceptual Inventory on the Evolution of Biological Organisms (CIEBO) were devised, with each item comprising a stem, an answer tier and a reason tier. The answer tier measures the content knowledge, while the reason tier measures the explanatory knowledge of learners. On the whole, respondents performed poorly for the answer and reason tiers of items, with only about half or less of students being able to select the correct options for the answer and reason tiers, and with students obtaining slightly higher mean scores for CIHE than for CIEBO. This highlights the prevalence of ACs in students regarding evolution and natural selection. The workshop would focus on the development of 2TMC items in a systematic manner, allowing teachers of different subjects (particularly Science subjects) to develop their own 2TMC items. The developed items can then be evaluated by peers as well as the author of the study, providing the groundwork to share common pitfalls and issues with 2TMC items, and tips for educators to utilise 2TMCs as teaching tools as well as diagnostic instruments.

Back to programme

(W383) LOWER SELETAR RESERVOIR TRAIL

Huazhi CHAN, *Christ Church Secondary School*
Sabrina JUMADI, *Christ Church Secondary School*

Abstract
Kolb's experiential learning theory presents a cyclical learning model comprising four crucial stages. According to the theory, learning becomes effective when a learner can have a concrete experience, make a reflective observation, form an abstract conceptualisation of an existing abstract concept, then apply and test the conceptualisation through active experimentation. In Christ Church Secondary School, experiential learning days have been a fixture on the school calendar since 2016. On experiential learning days, students across all levels participate in activities designed and facilitated by teachers from the various subject departments with the aim of promoting effective and meaningful learning that stretches beyond classroom learning in accordance to Kolb's experiential learning theory. One of the Science experiential learning programmes carried out by the school over a span of two days is the Lower Seletar Reservoir Trail for all Secondary Two students. This programme serves the dual purpose of engaging students in Science experiential learning, as well as promoting environmental awareness with the use of recycled and household materials in the activities. Teachers are deployed to stations according to their subject specialisations with the roles of monitoring the safety of students when they are carrying out experiments and facilitating group discussions. Activities and discussion questions are differentiated in order to cater to the different learning needs of students across the Express, Normal (Academic) and Normal (Technical) streams. The programme has taken on the format of an Amazing Race: Students are grouped within their classes and are challenged to complete group activities in eight stations spread across the Lower Seletar Reservoir Park within the shortest possible time. In each station, students experience a scientific phenomenon related to concepts within a Secondary Two Science topic which they have learnt or have yet to learn in the classroom. The experience is created through the doing of the activity under teacher supervision. Thereafter, students engage in group discussions over guiding questions on worksheets to reflect upon the experience, as well as to co-create knowledge and match suitable hypothesis or scientific theories to their observations. Following that, students carry out further experimentation to test their deductions and explanations. This programme has allowed students to develop their competencies in generating ideas, as well as to use observations and viewpoints to deduce or explain scientific principles individually and collaboratively. Besides reinforcing scientific concepts which have previously been taught in the classroom, the activities have also enhanced the learning of subsequent topics in the Secondary Two Science syllabus as students are equipped with common prior experiences which they can relate to in their learning that teachers could tap on for knowledge construction. In this workshop, we will share how Kolb's experiential learning theory can be implemented with simple yet meaningful experiments and tools to aid students in reflecting upon their experiences with minimal teacher guidance for the learning of Science.

Back to programme

(W423) CRAFTING LITERATURE APPRECIATION TASK

Chorng Shin WEE, *Hwa Chong Institution*
Gah Hung LEE, *Hwa Chong Institution*

Abstract
The chemical education scene at the Junior College level in Singapore (equivalent to the last two years of senior high school) is generally being perceived as demanding[1] and in many instances, the students are not able to relate what they have learnt to the real world. The syllabus has recently been updated to include learning experiences as part of the learning and teaching of this subject. The assessment is also updated which will include more application questions based on unfamiliar context. The application question usually appears in the form of a data-based or stimulus-based question where students need to answer questions based on the data and/or stimulus given. Since 2010, the chemistry unit in Hwa Chong Institution begun exposing the students to contemporary literatures. We started with the students in the science special programs and those doing H3 pharmaceutical chemistry where we shared with them research papers and the students are required to discuss and answer some open-ended questions following it. At appropriate juncture, we also conducted viva voce (oral assessment) with the students in order to gauge their appreciation and understanding of the literature. Beginning in 2013, some of the literature were condensed into readable bits and shared with the students in the main cohort. In addition, questions were crafted based on these condensed article in the form of performance tasks which was given to all students. This gave them the opportunities to be expose to novel applications beyond the syllabus. Over the past 8 years, we have shared with educators our work in various platforms such as IPSG, workshops and also in overseas conferences such as the 6th NICE (Network for Inter-Asian Chemistry Educators). Many educators we spoke to in such meetings highlighted that the work is admirable but the key to its success usually lies in the technical aspect in choosing a suitable article and crafting it into a reasonable literature appreciation task. The issues which many educators face was also in the ability to simplify the ideas/ data in the article to one that is suitable for the students and also the thought processes behind crafting such task. This workshop attempts to address some of the gaps faced by many educators by sharing some of the strategies we used and the challenges we overcame along the way. It is also our hope that at the end of the day, we can have a common folder for everyone to share the resources we find or crafted. Participants will get to learn: • to identify an appropriate literature and how to develop the content into a suitable task • to craft suitable activities (such as viva, collaborative learning) based on an appropriate literature. This workshop is relevant for those who teaches chemistry in senior high schools or universities.

Back to programme

MULTIMODALITY IN SCIENCE EDUCATION SEMINAR

Chairs:
Jennifer YEO, *National Institute of Education, Nanyang Technological University, Singapore*
Wendy NIELSEN, *University of Wollongong*

Presenters:
Theory section:

John AIREY, *Uppsala University & Stockholm University*
Maurice CHENG, Kristina DANIELSSON, Yuen Yi LO, & M. Y Angel., LIN, *Simon Fraser University*
Caroline HO, *Ministry of Education, Singapore*
Wendy NIELSEN, Helen GEORGOIU, Pauline JONES & Annette TURNEY, *University of Wollongong*
Russell TYTLER & Vaughan PRAIN, *Deakin University*
Len UNSWORTH, *Australian Catholic University*

[1]Jennifer YEO & [2]John GILBERT, [1]*National Institute of Education, Nanyang Technological University, Singapore,* [2]*The University of Reading*.

Practice section:

[1]Jennifer YEO, [1]Wai Lit WONG, [1]Daniel TAN, [1]Aloysius ONG, [1]Eugene LIM, & [2]Poh Hiang TAN, [1]*National Institute of Education, Nanyang Technological University, Singapore*, [2]*Academy of Singapore Teachers, Ministry of Education, Singapore*
Peter HUBBER, *Deakin University*
Russell TYTLER & Peta WHITE, *Deakin University*
Jonathan ADAMS, *English Language Institute of Singapore, Ministry of Education, Singapore*

Trevor VOLKWYN[1,2], John AIREY[1,3], Bor GREGORČIČ[2] & Filip HEIJKENSKJŐLD[2], [1]*University of the Western Cape,* [2]*Uppsala University,* [3]*Stockholm University*
Len Unsworth, Australian Catholic University

Multiple representations in science education have been an interest to scholars of varied fields – science educators, linguists, social semioticians, psychologists, etc, characterised by a myriad of theoretical perspectives that can be traced to as far back as the 1980s. Notable early theories including the dual coding theory (Pavio, 1986) and cognitive flexibility theory (Spiro et al., 1988), were used to explain why multiple representations are useful to learning. As focus on multiple representations in science learning changed from an interpretive perspective to that of constructivist, new terminologies borrowed from other fields and new models emerged.

To take stock of where we are and to chart where we are going in this field of research, this seminar brings together scholars with a common interest in multiple representations in science education, albeit different backgrounds. The aim is to explore the diversity of theoretical viewpoints and practical applications for classroom learning that each brings to bear in this area of research. The seminar is divided into two sessions, a theoretical focus in the morning and a practical focus in the afternoon. The seven papers presented in the theory-oriented session are representative of the different theoretical perspectives, frameworks and focus of current work in multiple representations in science education. They demonstrate the varied frameworks that are currently utilised in the field – systemic functional linguistics (Halliday, 1985), multimodality (Bateman et al., 2017; Jewitt et al., 2016; Kress, 2003), thematic patterns (Lemke, 1990), and legitimate code theory (2014). The foci in these papers extend from how these theoretical frameworks are used to inform teaching and learning of science with an emphasis on its representations, to constructing frameworks that can better inform science teaching and learning. In the practice-oriented session, the six papers present pedagogical approaches that focus on students' construction of representations to learn science, and strategies and resources that support students' engagement in representing and communicating science.

In this seminar, we will discuss these current frameworks and pedagogies in view of the traditional viewpoints and theories, while seeking clarity of definitions and evidence for how the current viewpoints inform teaching and learning. Discussion will also focus on charting new directions for research activities in order to achieve a sharper focus of contemporary perspectives in multiple representations and multimodalities in science.

Back to programme

Theory Session

THE CONCEPT OF AFFORDANCE IN TEACHING AND LEARNING UNDERGRADUATE SCIENCE

John AIREY, *Uppsala University & Stockholm University*

Since its introduction by Gibson (1979) the concept of affordance has been debated by a number of researchers. Most famous, perhaps is the disagreement between Gibson and Norman (1988) about whether affordances are inherent properties of objects or are only present when perceived by an organism. More recently, affordance has been drawn on in the educational arena, particularly with respect to multimodality (see Fredlund, 2015 for a recent example).

In the presentation the interrelated concepts of disciplinary affordance and pedagogical affordance will be presented. Both concepts make a radical break with the views of both Gibson and Norman in that rather than focusing on the perception of an individual, they refer to the disciplinary community as a whole. Disciplinary affordance is "the agreed meaning making functions that a semiotic resource fulfills for a disciplinary community". Similarly, pedagogical affordance is "the aptness of a semiotic resource for the teaching and learning of some particular educational content" (Airey, 2015). As such, in a teaching situation the question of whether these affordances are inherent or perceived becomes moot. Rather, the issue is the process through which students come to use semiotic resources in a way that is accepted within the discipline. In this characterization then, learning can be framed in terms of coming to perceive and leverage the disciplinary affordances of semiotic resources.

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Back to programme

Theory Session

KEEPING THE MAIN THING THE MAIN THING IN TRAVERSING MULTIMODAL MEANING-MAKING IN SCIENCE

Caroline HO, Ministry of Education, Singapore

This paper contributes to the discussion on multimodality by offering perspectives taking off from the notion of disciplinary literacy (Moje, 2007, 2008; Shanahan & Shanahan, 2008, 2012) set against the Singapore context with the current strategic thrusts of twenty-first century competencies (MOE, 2011) and what effective communication (ELIS, 2015) entails in content areas. Attention is given to scientific literacy, in focusing not only on the linguistic but also the nonlinguistic domains, particularly with meaning-making realised increasingly in multimodal ways (Kress et al,2001; Lemke, 1989).This extends discussion to issues related to multimodal literacy (Jewitt & Kress, 2003) framed by constructivist underpinnings (Bruner, 1990; Papert, 1993; Vygotsy, 1978) and supported by social semiotics theory (Halliday, 1978; Lemke, 1989). Building up students' skills in responding, connecting and re-contextualizing information in the multimodal environment (Kress, 2003; Luke, 1996) calls into question what it means to effectively mediate content learning with the interplay of various modes for different purposes (Baldry, 2001, Kress & van Leeuwen, 2001). Traversing the diverse landscape of multimodal meaning-making with its attendant, competing demands brings to the fore the need for establishing the principles, priorities and purposes required for making explicit what matters and what is valued in science. This presentation raises the alert for keeping the main thing the main thing, and asks if we are even clear as to what the main thing is in teaching and learning Science. As we seek to support students in thinking, talking, reading, writing, representing the way scientists do, this is not only appropriate but essential.

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Back to programme

THE CONSTRUCTION OF MEANING THROUGH IMAGE-LANGUAGE INTERACTION IN STATIC VISUALIZATIONS IN SCHOOL SCIENCE.

Len UNSWORTH, *Australian Catholic University*

There is a noticeable progressive change in the form of static representations in school science learning materials, and perhaps also in student created representations, from visualisations accompanying text to the integration of text and image in page or page segment based infographic formats. Limited research attention has been given to this form of representation in science and specifically little attention has been given to the nature and functional roles of the text interpolated into image representations (Danielsson & Selander, 2016; Hiippala, 2015; Peterson, 2016). An understanding of the range of different types of text interpolation, their various functional roles in meaning making and their relationship to the image representation is important developing pedagogies to mediate students' negotiation and creation of such representations. This presentation outlines current research adapting systemic functional linguistic accounts of linguistic resources for aggregating and synthesising knowledge building within texts (Martin, 2013; Martin, 2017), to the increasingly prominent multimodal infographic forms of school science representation. A tentative taxonomic account of the nature and function of text interpolations in such representations will be discussed. This will be illustrated principally through data from current Australian school science textbooks, but will also include reference to some student created responses in a project investigating multiliteracies for addressing disadvantage in senior secondary school science education (Unsworth, Tytler, Love, O'Halloran, & Humphrey, 2016-2019). Issues involved in extending the proposed theoretical framework to dynamic forms of infographics and to investigating the relationship between students' competence in interpreting and creating such texts to the development of their critical understanding and their achievement in school science will also be canvassed.

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Back to programme

A FRAMEWORK OF SCIENTIFIC EXPLANATION, USING HALLIDAY'S MODEL OF LANGUAGE AS AN ORGANISING STRUCTURE

Jennifer Yeo, *National Institute of Education, Nanyang Technological University, Singapore*
John Gilbert, *The University of Reading*

The construction of scientific explanation entails one to be fluent in coordinating multiple modes of representations in conceptualizing how or why a phenomenon comes about. This presentation presents a framework of scientific explanations that makes use of Halliday's model of language as an organising structure. The framework of scientific explanation identifies three aspects (layers) that students need to attend to in constructing of a scientific explanation: (1) belief in the nature of science, (2) function of an explanation, and (3) meta-functions of language. These can be perceived to be parallel with the dimensions in Halliday's (1985) model of language – context of culture, context of situations and language. In Halliday's model, he perceives communication as an instantiation of its culture, realized through language use in a specific situation. In a similar vein, the construction of a scientific explanation, whose conceptual nature is oriented towards the audience, is an instantiation of one's belief in the nature of science (culture) through the selection and use of semiotic resources (language). In this respect, the framework captures the epistemological, conceptual and representational characteristics of science. The aspect of function relates to the instantiation of the culture of science through the different types of explanations that can be produced, which is further characterised by its coherence, orientation to audience and precision. The bottommost layer relates to how the function of an explanation is realized with language resources – form, abstractness and representational scheme. Among the value of this framework is its potential in bridging the language of social semiotics with science education. Teachers typically find it difficult to master the language of systemic functional linguistics (SFL) to analyse the language demands of scientific texts. This framework contextualizes SFL model in the language of science, hence teachers do not need to learn a new language in order to analyse the representation/language demands of scientific texts (explanations), increasing its potential of utility.

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Back to programme

HOW FAR CAN MULTIMODAL TEACHING GO IN SCIENCE TEACHING?

Maurice M.W. CHENG, *The University of Hong Kong*
Kristina DANIELSSON, *Stockholm University*
Yuen Yi LO, *The University of Hong Kong*
M.Y. Angel LIN, *Simon Fraser University*

Teaching and learning of science is multimodal by nature. Visual modes play a key role in them. Visual mode bears a higher affordance than verbal mode in representing concrete 'structures' and – with the use of appropriate symbols – 'processes'. There is an issue with the role of multimodal teaching, particularly the use of visual mode, in supporting students' learning of non-structure and non-process abstract concepts. This could be a challenge because these concepts are 'abstract' (as contrast to 'concrete' according to Paivio), meaning that they are less likely to trigger and be supported by visual mental representations.

Curricula around the world (e.g., in NGSS, Grades 7-12 Science/ Integrated Science curricula in Hong Kong) emphasize intellectual tools that transcend topics and subjects. They are called crosscutting concepts or unifying concepts. Unifying concepts include 'forms and functions', 'change and constancy', 'systems and organizations', 'evidence and models'. So far, little resources are available to support the teaching of these concepts. We would like to explore what multimodal teaching can offer to facilitate students' learning of these abstract concepts.

In the talk, we will present a classroom episode in which Swedish primary school students constructed multimodal representations to explain gaseous expansion at a submicro level. Such construction may touch upon the unifying concepts 'change and constancy'. We will report a multimodal analysis of the classroom episode. We also analyse it based on Lemke's theory of thematic patterns, and suggest how the classroom episode may be extended to the teaching of 'change and constancy'.

Back to programme

THEORETICAL PERSPECTIVES ON LEARNING WHEN STUDENTS CREATE MULTIMODAL DIGITAL EXPLANATIONS

Wendy NIELSEN, *University of Wollongong*
Helen GEORGIOU, *University of Wollongong*
Pauline JONES, *University of Wollongong*
Annette TURNEY, *University of Wollongong*

Our research examines how tertiary science students learn and communicate science knowledge by creating multimodal digital explanations or 'blended media' (Hoban, Nielsen & Hyland, 2016) for a particular audience. These 3-5 minute mini-movies deploy a number of semiotic resources (O'Halloran et al., 2013) that weave together as a coherent and well-developed explanation of a science concept for a particular audience. We draw from perspectives in multimodalities (Bateman et al., 2017; Jewitt et al., 2016; Martin, 1992; Painter et al., 2013; O'Halloran, 2008, 2011; van Leeuwen, 2005) to consider these artefacts and the ways that scientific knowledge is represented; how an interpersonal appeal is created for the viewer; and how they are organized according to a 'compositional sequence' (Bateman, 2008). We also draw upon a conceptual framework derived from Legitimation Code Theory (Maton, 2014) as a sociological perspective on students' knowledge building within and across their representations. Theoretically and analytically, we wonder: what meaning is the creator intending to demonstrate (and how effective is it?); for whom is meaning being made? (and, how?); and how are meanings condensed and integrated?

Where to next? As we refine our analytic tools and work farther into the data set that now includes 75+ blended media artefacts and 35+ interviews with their makers as well as instructors, we are challenged by the integration of theoretical perspectives in this interdisciplinary work; instructors' conceptions of these complex tasks; and more generally, the assessment context in tertiary science subjects.

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Back to programme

REASONING IN SCIENCE THROUGH REPRESENTING ACROSS MODES

Russell TYTLER, *Deakin University*
Vaughan PRAIN, *Deakin University*

Traditional cognitivist accounts of reasoning and learning through multimodal representations tend to treat reasoning as occurring ‘in the head’, with representations caste as ‘tools’ leading to, or subsequently expressing ideas/mental models that are distinct from the representational processes through which they were created or modified. We argue for a pragmatist perspective that positions the representation construction process as, potentially, reasoning, involving the generation and orchestration of visual, spatial, and textual claims leading to explanations and the solution of problems in inquiry science. In advancing this position we will draw particularly on data from micro ethnographic analyses of an extensive video data set generated in the ‘Science of Learning’ classroom with multiple tilt and track video cameras, involving pairs of students grappling with open ended tasks. We examine the diverse ways in which drawing was coordinated with other modes together with material exploration, to reason and learn, and the conditions under which this occurred. We will focus particularly on reasoning ‘through’ and ‘from’ drawing to exemplify the way drawing productively constrains thinking, supporting a focus on visual and spatial aspects of phenomena. We describe, with examples, how the drawing process makes possible co-representation and monitoring of ideas through opening up thinking to inspection, and how reasoning through and with drawing inevitably involves re-description and orchestration across multiple modes. We describe an ongoing program of research investigating the implications of these perspectives for characterising scientific disciplinary literacy.

Back to programme

Practice-oriented Session

AN IMAGE-TO-WRITING APPROACH TO PRIMARY SCIENCE LEARNING: ENACTMENT AND CHALLENGES

Jennifer YEO, *National Institute of Education, Nanyang Technological University, Singapore*
Wai Lit WONG, *National Institute of Education, Nanyang Technological University, Singapore*
Kim Chwee Daniel TAN, *National Institute of Education, Nanyang Technological University, Singapore*
Aloysius ONG, *National Institute of Education, Nanyang Technological University, Singapore*
Eugene LIN, *National Institute of Education, Nanyang Technological University, Singapore*
Poh Hiang TAN, *Ministry of Education, Singapore*

This presentation introduces an image-to-writing approach to primary science learning. This approach helps students learn abstract scientific concepts as they are engaged in the translation of images to textual representations. Formative assessment strategies are used to elicit information about students' understanding of abstract science concepts such as temperature and heat from the images they produce, with which teachers develop strategies to help them achieve deeper conceptual understanding as well as communicate with appropriate scientific language. However, as pointed out by different researchers (e.g., Khan, 2011; Prain & Tytler, 2012; Waldrip & Prain 2013), a representational approach of teaching makes demands on the teacher's skills in facilitating formative assessment. This presentation focuses on one of research objectives of a larger research agenda, in particular to identify pedagogical strategies that are effective in supporting concept learning through an "image-to-writing" approach, and the knowledge and skills teachers need to implement this pedagogy. From our first two research cycles, we found that while a discursive pattern of "explore – work-on – review" (Mortimer & Scott, 2003) might help teachers with the macro-structure of talk, they have problems with the pedagogical micro-actions within each of these stages. For example, the teachers in our study seldom helped students in making sense of the diverse ideas offered by students during "explore" move before taking up an idea to work on. The sequence of uptake of ideas when "working on" students' ideas was also problematic (e.g., discussing the measurement of temperature before understanding what temperature is). From our focused conversation with the teacher participants, we attribute the observations to a lack of understanding the content knowledge at the meta-level and the tendency of teachers to rely on the design of a worksheet to sequence the ideas to be discussed. From the findings, we draw implications to pedagogical content knowledge that needs to be developed to help teachers conduct a representational-based lesson effectively.

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Back to programme

REPRESENTATION CONSTRUCTION: A RESEARCH DEVELOPED GUIDED INQUIRY PEDAGOGY FOR SCIENCE EDUCATION

Peter HUBBER, *Deakin University*

This presentation describes the development and implementation of a guided-inquiry approach to teaching science over a 10 year research programme which reflects the increasing attention given to the role of representation in learning science as well as knowledge creation in science. This representation construction approach (RCA) involves challenging students to generate and negotiate the representations (text, graphs, models, diagrams) that constitute the discursive practices of science, rather than focusing on the text-based, definitional versions of concepts. In working with teachers in the development and refinement of the approach a design-based research methodology was employed. The investigation of the approach, and teachers' experience involved video capture and analysis, and teacher interviews whilst documentation and analysis of student learning occurred through analysis of class discussion through whole class and small group video capture, collection of student artefacts, pre- and post-tests, and student stimulated recall interviews. The RCA has been successful in demonstrating enhanced outcomes for students, in terms of sustained engagement with ideas, and quality learning, and for teachers enhanced pedagogical knowledge and understanding of how knowledge in science is developed and communicated. RCA opens up new directions and emphases for teachers such as a change from students using their notebooks to transcribe distilled science knowledge provided by the teacher to the use of notebooks as learning journals. There is also a new emphasis for the teachers in developing students' meta-representational competence in addition to developing their conceptual understanding of science.

Back to programme

LEARNING IN STEM THROUGH CONSTRUCTING, EVALUATING AND ORCHESTRATING REPRESENTATIONAL SYSTEMS

Russell TYTLER, *Deakin University*
Peta WHITE, *Deakin University*

This paper will describe classroom research based on the work of Lehrer and Schauble, in which 10 year old students measure, invent, compare, and revise data displays to explore ideas about data variation related to their teacher's armspan. We argue that through invention and classroom based negotiation, students' vision of variability is transformed, to focus on its underlying structure. Data included video capture of collaborative reasoning and of classroom discussion, student artefacts, and interviews. Two key sessions in the sequence took place in a 'Science of Learning' classroom with multiple video cameras and microphones, capable of capturing pairs of students' collaborative reasoning as they invented their displays. Through tracking students' growth in ideas about data variation and measures of centre, we argue that the construction and negotiation of measure opens up important insights into data variation not normally focused on in school. We link this process to a program of research we have been advancing over time that advocates and investigates a 'representation construction' guided inquiry approach to science in which students construct/invent representations in response to challenges, and compare and refine these with teacher guidance. We use experience from diverse sequences to discuss the key features of approaches to learning grounded in representational work.

Back to programme

EXAMINING THE COMMUNICATIVE POTENTIAL OF VISUAL REPRESENTATIONS TO LEARN SCIENCE

Jonathan ADAMS, *Ministry of Education, Singapore*

This presentation draws on a study which examined the role of visual representations (VRs) by teachers to engage learners in using spoken and visual communication to learn Science. The study employed ethnographic approaches to collect and analyse classroom data as 'snapshots of practice' from four primary classes and six secondary classes in Singapore schools. The data were transcribed and analysed from the perspective of language by a team from the English Language Institute of Singapore.

The findings identified that when teachers engaged students in Science communication around VRs, their questions appeared to be concentrated on eliciting a few of the Science skills defined in the Ministry of Education Science syllabuses, with some VRs being used more frequently than others. This indicated more communicative potential could be taken up to engage students in a wider range of Science communication across a broader spectrum of VRs.

The study also found that as well as engaging students in a variety of activities such as annotating and reproducing VRs used in class, teachers providing opportunities for students to create their own original VRs to represent Science meanings appeared effective for what could be understood as communicating effectively in Science. These activities were observed to show high levels of student engagement with opportunities for students to deepen their learning through representing meaning in multiple modes (spoken, written and visual) and through a range of communicative activities which accompanied the creation of VRs.

Back to programme

MULTIMODAL TRANSDUCTION IN UPPER-SECONDARY SCHOOL PHYSICS.

Trevor VOLKWYN, *University of the Western Cape, Uppsala University*
John AIREY, *University of the Western Cape, Stockholm University*
Bor GREGORČIČ, *Uppsala University*
Filip HEIJKENSKJŐLD, *Uppsala University*

In this study we video-filmed upper-secondary physics students working with a laboratory task designed to encourage transduction (Bezemer & Kress 2008) when learning about coordinate systems.

Students worked in pairs with an electronic measurement device to determine the direction of the Earth's magnetic field. The device, IOLab, can be held in the hand and moved around. The results of this movement are graphically displayed on a computer screen as changes in the x, y and z components of the Earth's magnetic field. The students were simply instructed to use the IOLab to find the direction of the Earth's magnetic field and mark its direction using a red paper arrow.

A full multimodal transcription of the student interaction was made (Baldry & Thibault 2006). In our analysis of this transcription, three separate transductions of meaning were identified—transduction of meaning potential in the room to the computer screen, transduction of this meaning to the red arrow, and finally transduction into student gestures. We suggest that this final transduction could not have been made without the introduction of the arrow, which functioned as a coordinating hub (Fredlund et al 2012).

We recommend that teachers should carefully think about the resources in a task that may function as a coordinating hub and should also look for student transductions in their classrooms as confirmation that learning is taking place.

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Back to programme

VISUALIZATIONS IN MATRICULATION LEVEL SCIENCE EXAMINATIONS: MAPPING THE NATURE AND EXTENT OF IMAGE CREATION REQUIRED IN STUDENT RESPONSES.

Len UNSWORTH, *Australian Catholic University*

This session presents a mapping over a period of five years of the nature of and extent of image creation required in the external examination in physics, chemistry and biology in the final year of secondary school as part of the Victorian Certificate of Education in the State of Victoria in Australia. Current and emerging taxonomies of image types (Kress & van Leeuwen, 2006; Roth, Pozzer-Ardhenghi, & Han, 2005) are drawn on to show the variation visualization representation required of students within and across subject areas and within and across the period that is mapped. Case studies address the variation in the representation of the same phenomenon required in responding to different questions in the same topic area. The required visualizations are then related to subsequently published example responses and to examiners' comments on the questions. Implications are drawn for the application of visualization representation pedagogies in senior secondary school science.

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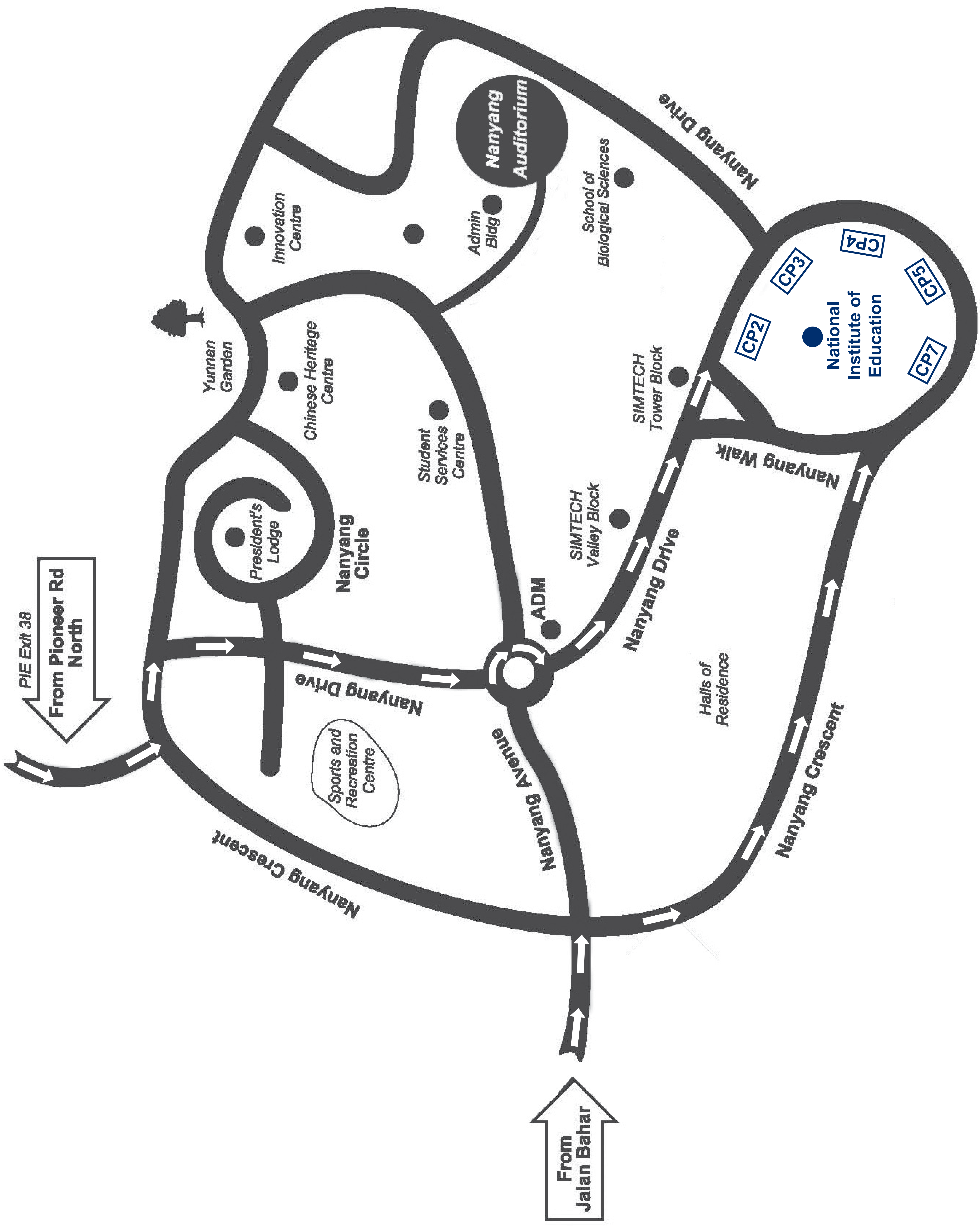
Back to programme

LOCATION MAPS

NIE Location Map



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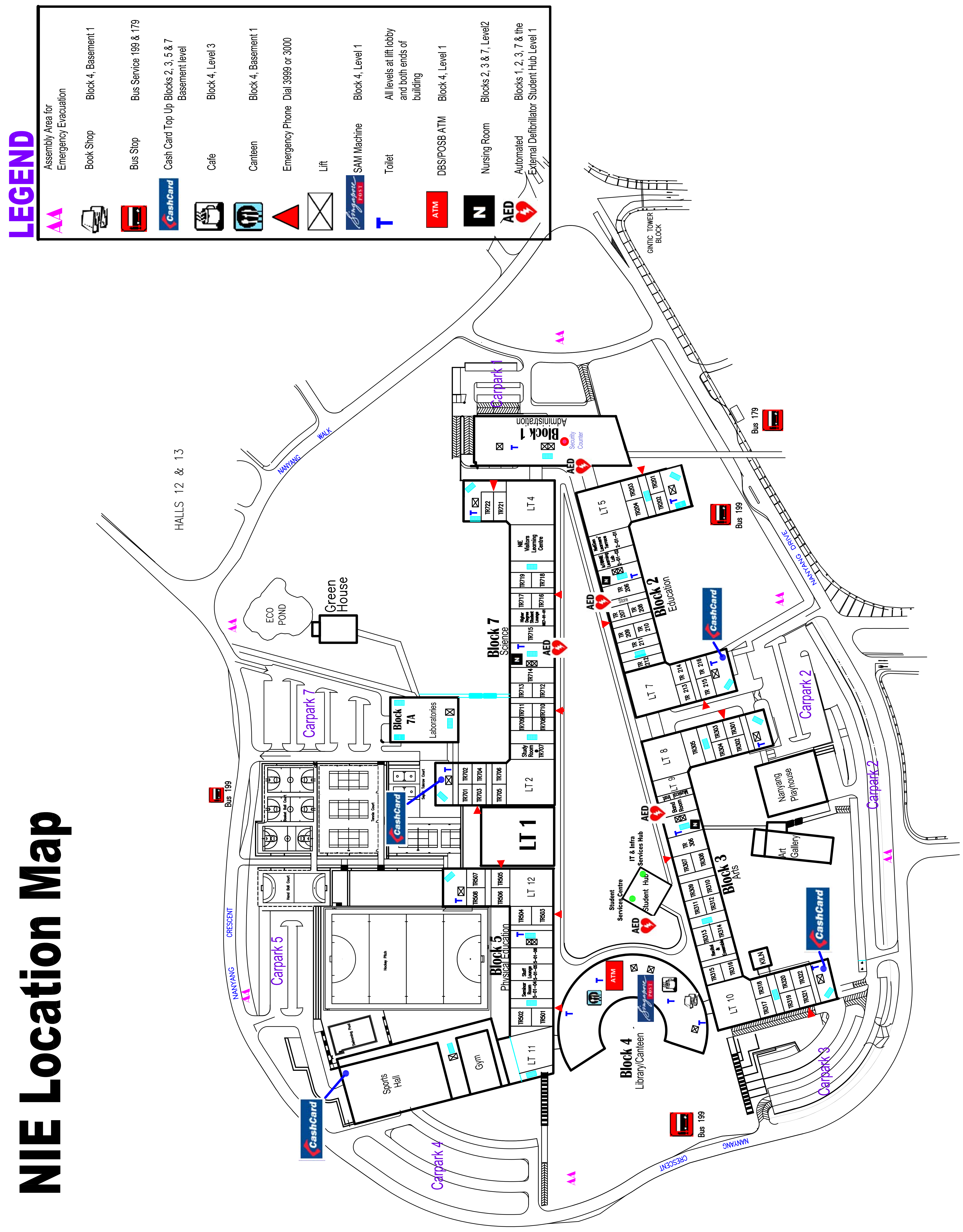
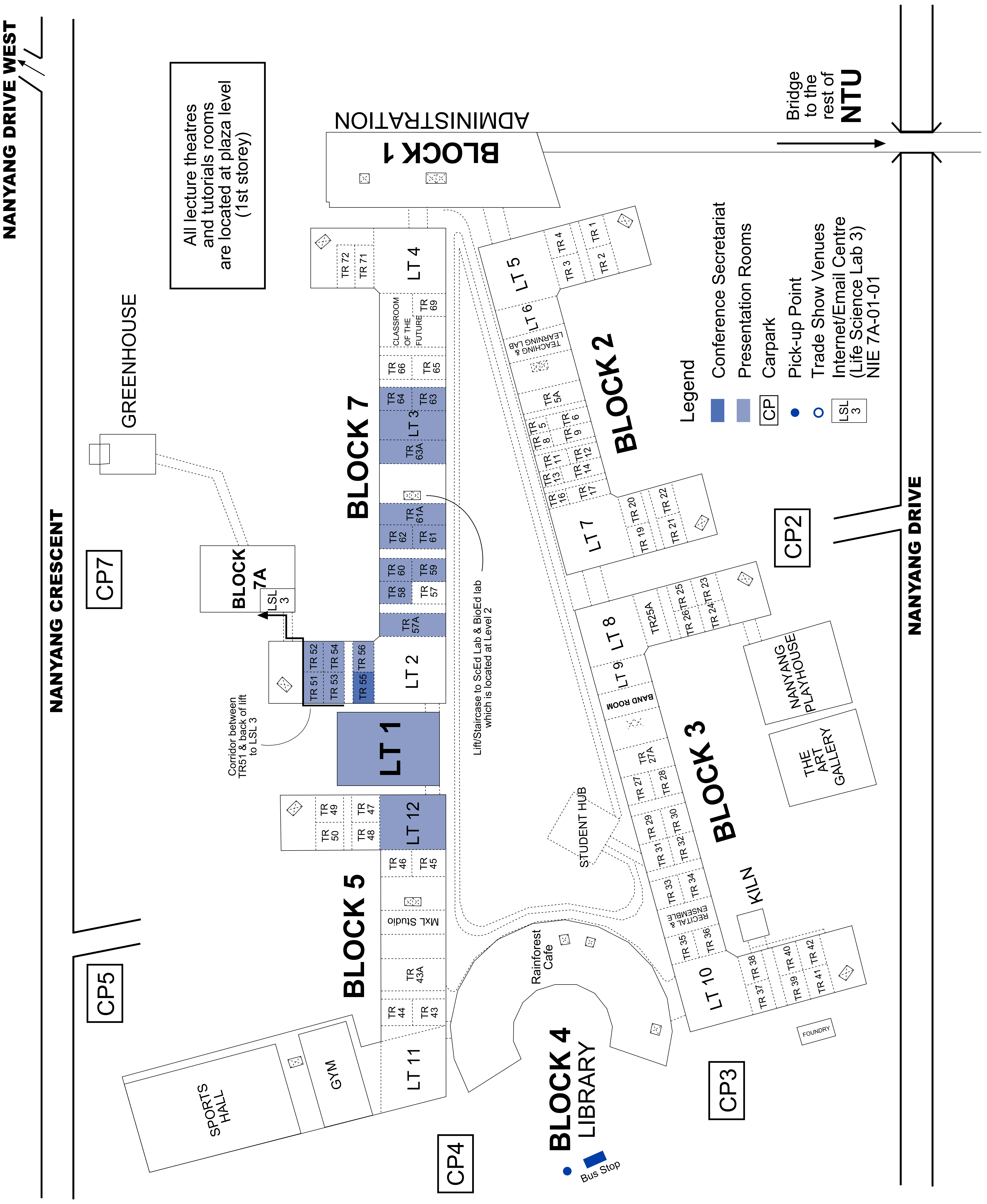


Conference Map



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