

ASERA 52 – 2021

Conference Program*

Drawing together science education researchers from Australia, New Zealand, the region, and the world.

Sharing cutting-edge research methods and findings in science education from pre-school, school, university, technical and informal settings to inform practice.

When: June 29 – July 2, 2021

Where: Hosted by University of South Australia

Format: Originally a blended model of face-to-face and virtual participation. Due to COVID restrictions, the conference was moved to totally online.

Conference organiser: Kathy Paige, Bruce White, Yvonne Zeegers, University of South Australia

Website creator: David Geelan

Conference Welcome and Opening

Tuesday 29th June between 6.30 -7.30 pm Central Australian Time. Please pour yourself a drink and join breakout rooms for a discussion with science education research colleagues

There was a suggestion from Jenny Martin to either be adventurous with your screen background (Selecting where you would really like to be) Or dress up along the theme of COVID Dreaming. So, we are open to either or neither. It would be great to have you in the discussion.

Parallel Sessions

The first parallel sessions of the Conference will commence at 9.00 am on Wednesday 30 June online.

Conference Closing

The Conference will conclude at lunch time on Friday 2nd July.

**Note: this program was compiled after the conference, based on the conference website. The conference was changed to being completely online the week before.*

Instructions

Instructions for Session Chairs

Each presentation timeslot is strictly 40 minutes with 20 minutes for presentation and 17 minutes for discussion. To ensure the program runs to schedule, please adhere strictly to the program as provided. If a presenter does not arrive for their slot, please do not move other presenters forward, but rather wait until the scheduled time to begin the next presentation.

Instructions for Presenters

Each presentation timeslot is strictly 40 minutes with 20 minutes for presentation and 17 minutes for discussion. Please be in your session Zoom room 10 minutes prior to the start of your session to assist all sessions to run on time. Your Chair will brief you about the format of your session before the commencement of presentations.

Online presentations will be live via Zoom Video Conferencing and so all presenters will need to ensure that they are available during their scheduled presentation time. The Chair will manage questions from the face-to-face participants and there will be an online facilitator to manage questions from the online participants. Online presenters will need to share their screen if using PowerPoint or similar.

Instructions for Poster Presenters

Poster presenters are expected to present during their designated poster session, please refer to the program to see your presenting time.

Online poster presenters will need to email a PDF of your poster to Bruce.White@unisa.edu.au by the **4th June** so that it can be uploaded to the conference website.

Program – Wednesday 30 June

Session	Room 1	Room 2	Room 3	Room 4
W1 (a)	<p>Symposium Marilyn Fleer Programmatic research on STEM concept formation: Conceptual PlayWorlds as an educational experiment in early years</p> <p>Paper 1: Marilyn Fleer, Glykeria Fragkiadaki, Prabhat Rai</p>	<p>Tracey-Ann Palmer ScienceSing: Inspiring upper primary students to engage with science through song</p>	<p>Joseph Ferguson, Peta White School strikers enacting politics for the environment – Daring to think differently about science and environmental education</p>	<p>Carrie Swanson Exploring how the Figured Worlds of five Auckland Primary/Intermediate schools affects the performance of science</p>
W1 (b)	<p>Paper 2: Tanya Stephenson, Marilyn Fleer, Glykeria Fragkiadaki</p> <p>Paper 3: Prabhat Rai, Marilyn Fleer, Glykeria Fragkiadaki</p> <p>Paper 4: Glykeria Fragkiadaki, Marilyn Fleer, Prabhat Rai</p>	<p>Marianne Logan, Amy Cutter-Mackenzie-Kowles, Lexi Lasczik, Antonia Canosa, Mahi Paquette Looking at the intra-actions within/around/between</p>	<p>Efrat Eilam The Benefits of Establishing a Climate Change Subject in the Curriculum</p>	
Morning tea				

W2 (a)	<p>Christina Guarrella, Jan van Driel, Caroline Cohrssen Assessment of science learning in early childhood: What influences teachers' assessment practice?</p>	<p>Leonie Rennie Being Systematic in Science: A taxonomic biography of the Shark Bay Pearl Shell</p>	<p>Yoon-Hee Ha, Hyeonjeong Shin, Hyun-jung Cha, Chan-jong Kim The epistemic criteria used by pre-service teachers for evaluating the climate change model constructed by students</p>	<p>Cathy Bunting, Dayle Anderson, Dianne Christenson Investigating students' views of their science capability development</p>
W2 (b)	<p>David Lloyd Learning Locally: TOSCG and Our Future</p>	<p>Yaela Golumbic, Alice Motion Citizen science in the Lab: Exploring unique learning experiences</p>	<p>Vaille Dawson, Efrat Eilam, Peta White, Helen Widdop Quinton, Gusti Agung Paramitha Eka Putri, Agung Wijaya Subiantoro, Sakari Toppanen, Tuba Gokpinar, Daphne Goldman, Orit Ben Zvi Assaraf, Rishi Krishnmoorthy, A multi-country comparison of climate change curricula in secondary school</p>	<p>Changmi Park, Hyun-Jung Cha, Seok-Hyun Ga, Chang Hyeon, Eom Sung-Eun, Lim Ji-Hye, Kwon Seoha Na, Hyeijin Um, Chan-Jong Kim Development and Application of IoT-based STEAM Program for Citizen Scientist Activity</p>

W2 (c)	Pauline Roberts Local walks to engage young children in science	Reece Mills, Terri Bourke Teaching and leading practices of primary school teachers with a science specialism	Veerendra Prasad, Helen Widdop Quinton, Efrat Eilam Teaching and Learning Climate Change Education: A Case Study of Upper Secondary Victorian School	Jeff Brown, Karen Murcia, Brad Gobby A genealogical study interrogating the STEM education agenda in Australia
Lunch				
W3 (a)	Melanie O’Leary, Bruce White, Yvonne Zeegers Science teachers’ perceptions of what is important in STEM	John Willison Metacognitive outcomes of research skill development across a science degree	Julia Hill, Jan van Driel, Wee Tiong Seah, Margaret L Kern Developing an understanding and model of Australian student wellbeing in science education	Felicity McClure, Mihye Won, David Treagust Science teachers’ perceptions of creative thinking as a general capability
W3 (b)	Lindsey Conner Technology as integrator in STEM – co-curation and co-creation	John Kennedy, Simon Leonard Forming an understanding of students’ attitudes towards school Science	Elvia Shauki, Destri Fitriani, Alfa Rahmiati Engaging the Most Vulnerable: Challenges in Achieving Learning Outcomes during the COVID-19 Pandemic	Leana Coleman, Kathy Paige, Graham Hardy Embedding critical and creative thinking in the lower secondary science curriculum: challenges and opportunities

W3 (c)	<p>Magdalena Kersting, Rolf Steier, Grady Venville Exploring participant engagement during an astrophysics virtual reality experience at a science festival</p>	<p>Ahmad Basheer, Naji Kortam, Ayshi Sindian The level of green chemistry and sustainability awareness among pre- and in-service teachers in Israel, and their attitudes towards environmental education</p>	<p>Romy Hidayat, Febrina Sulistiawati, Elvia Shauki Experiencing Online Learning During Global Pandemic COVID-19: A Study in Health Education</p>	<p>George Aranda, Joseph Paul Ferguson Computational thinking, creative thinking</p>
W4 (a)	<p>Poster Session</p> <p>Maurizio Costabile Complex Immunological Concepts Can Be Effectively Taught Via Interactive Simulations</p> <p>Miranda Ge, Jonathan Li, Amanda Berry, Julia Lamborn An Investigation of Children's, their Parents' and their Teachers' Perceptions of Engineers and Engineering</p>	<p>Peter Ellerton Teaching the nature of science through an understanding of argument structure</p>	<p>Rui Wang, Aaron Britton, Harriett Godfrey, Aidan Feeney, Michelle Ellefson Executive functions and the suppression of naïve thinking in science education: a cognitive psychology task exploring the relationship between inhibition ability, cognitive flexibility and science learning</p>	<p>Symposium Kim Nichols Multi-Organisational Collaboration to Develop A Sustainable Model of Stem Professional Learning</p> <p>Paper 1: The STEM PLP Kim Nichols, Chae Swindell</p> <p>Paper 2: A Case Study School Rose Wood, Mel O'Brien, Hailey Johnson</p> <p>Paper 3: Impact and Sustainability of</p>

W4 (b)	<p>Shu-Chiu Liu Assessing undergraduate students' systems thinking competency using a scenario-based tool</p> <p>Siamak Mirzaei, Mandi Dimtriadis, Trent Lewis, Mirella Wyr Online Design Thinking Professional Development for School Teachers</p> <p>Hayashi Nakayama, Tomokazu Yamamoto Examination of a role-play-based school science lesson on electric current including programming activities</p> <p>Min-Erh Wei, Ching-Ting Hsin Exploring the teaching strategies and effect of a STEM project-based module for young indigenous children in Taiwan</p>	<p>Sally B. Gutierrez, Moonhyun Han Female elementary student's social construction of epistemic emotions: Effects on her patterns of participation in small-group scientific argumentation and modeling</p>	<p>Seamus Delaney Establishing a chemistry education research-oriented professional learning community with teachers through co-design methodology</p>	<p>the STEM PLP Reshma Parveen, Kim Nichols, Joseph Nagy</p>
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Program – Thursday 1 July

Session	Room 1	Room 2	Room 3	Room 4
T1 (a)	<p>Symposium</p> <p>Larry Bencze Pro-active Teaching for Eco-Just Re-worldings: Reinforcing Application-based Learning</p>	<p>Angela Fitzgerald, Kimberley Pressick-Kilborn The push or the pull? Investigating tensions and possibilities in two science teacher educators' return to schools</p>	<p>Peta White, Russell Tytler, Joanne Mulligan, Melinda Kirk Linking mathematics and science productively</p>	<p>Jamil Suprihatiningrum, Carol Aldous, Carolyn Palmer Meeting the challenges of accessibility for science inclusive classrooms: Indonesia's portrait</p>
T1 (b)	<p>Paper 1: Sarah El Halwany, Majd Zouda, Minja Milanovic, Nurul Hassan, Jasmine Yeung, Larry Bencze</p> <p>Paper 2: Jasmine Yeung, Sarah El Halwany, Nurul Hassan, Minja Milanovic, Majd Zouda, Larry Bencze</p> <p>Paper 3: Majd Zouda, Sarah El Halwany, Nurul Hassan, Minja Milanovic, Jasmine Yeung, Larry Bencze</p> <p>Paper 4: Larry Bencze, Dave Del Gobbo, Sarah El Halwany, Minja Milanovic, Nurul Hassan, Jasmine Yeung, Majd Zouda</p>	<p>Linda Hobbs Criteria for defining teaching out-of-field: Representing a complex phenomenon</p>	<p>Wendy Nielsen, Helen Georgiou, David Geelan, Angela Fitzgerald Reflections on running an online conference during a global pandemic</p>	<p>William Palmer Storytelling: Chemists, Crime, Fraud and Scandal</p>

Morning tea				
T2 (a)	<p>Heather McMaster, Christine Preston, Hailan Wang A macroscopic model introducing the particle nature of matter to upper primary school students</p>	<p>Russell Tytler, Vaughan Prain Transduction as fundamental to learning science</p>	<p>Nicholas Ruddell, Holly Randell-Moon Indigenous Automation in the Budj Bim eel traps and Brewarrina fish traps</p>	<p>Symposium Mihye Won Using immersive virtual reality to enhance learning of science – design and evaluation of science learning and user experiences</p>
T2 (b)	<p>Lina Aviyanti, Carol Aldous, Penny Vandeur Investigating the factors that foster and hinder understanding of physics concepts among prospective physics teachers</p>	<p>Anne Pillman, Lindsay Conner Why didn't they transfer? – factors affecting the transfer of science concepts by year 6 students</p>	<p>Kimberley Wilson, Phillip Dreise Embedding principles of Indigenised learning into tertiary primary science education curriculum</p>	<p>Paper 1: Mihye Won, Dewi Ungu, Henry Matovu, David Treagust, Mauro Mocerino, Roy Tasker & Chin-Chung Tsai</p> <p>Paper 2: Henry Matovu, Dewi Ungu, Mihye Won, David Treagust, Mauro Mocerino, Roy Tasker, Chin-Chung Tsai</p> <p>Paper 3: Dewi Ungu, Henry Matovu, Mihye Won, David Treagust, Mauro Mocerino, Roy Tasker, Chin-Chung Tsai</p>
T2 (c)	<p>Suarman Halawa, Ying-Shao Hsu, Wen-Xin Zhang Analysis of Instructional Designs for Promoting Inquiry Practices in the Physics Curriculum Standard Documents and Textbooks</p>	<p>Connie Cirkony, Glykeria Fragkiadaki, Richard Gunstone School science – Thoughts on an approach to rethinking what students learn and how they might be better engaged</p>	<p>Senka Henderson, Donna King Emotional responses of middle years students when writing two different Biostories using computers</p>	<p>Lihua Xu, Chris Speldewinde Interdisciplinary learning in mathematics and chemistry: A case study of two primary classrooms</p>

Lunch				
AGM				
T3 (a)	Sarika Kewalramani, Nikolai Veresov Multimodal Creative Inquiry: theorising a new approach for children's science meaning making in early childhood education	Yi-Fen (Yvonne) Yeh Learning Nature of Science through Inquiry-based Reading	Keith Skamp, Eddie Boyes, Martin Stanisstreet Students' willingness to act on their beliefs in reducing global warming as they age (Grades 6-10): Comparative changes in culturally different countries	Katrina Elliott, Kathy Paige Three case studies: valuing science in the middle school – students, teachers and parents
T3 (b)	Ching-Ting Hsin, Hsin-Kai Wu, Jyh-Chong Liang Factors Predicting the Science Teaching Practices of Kindergarten Teachers in Indigenous Areas in Taiwan	Jenny Martin University teachers' design for preservice teacher learning in primary science education units in Australia: a pilot study	Hyeonjeong Shin, Suhyun Seo, Chan-Jeong Kim Exploring Students' Agency concerning Climate Change through Action-oriented School Club Activity	Kylie Walters, Brendan Bentley Cognitive Load Theory and the human movement effect
T3 (c)		Jinglu Zhang Factors Affecting the Assessment Quality of Students' Scientific Argumentation Competency	Rachel Sheffield, Rekha Koul Sustainability and Environmental literacy: Examining understanding, behaviour and attitudes of 1st year tertiary students	Naji Kortam, Ahmad Basheer, Nibal Barbara The Effect of Simulation-based Biology Teaching on Students' Achievement and Attitudes toward Science

Program – Friday 2 July

Session	Room 1	Room 2	Room 3	Room 4
F1 (a)	<p>Symposium Alberto Bellocchi Contemporary Inquiry on Emotion and Affect in Science Education: Expanding the Research Programme</p>	<p>Brady Jack Why perceptions of ecological stimuli shape students’ SSI learning interest and enjoyment</p>	<p>David Treagust, David Blair Time to Challenge the Limitations of What Science Concepts are Taught in Primary School</p>	<p>Coral Campbell, Lihua Xu, Linda Hobbs Research-informed frameworks to support teacher professional learning and school change in STEM</p>
F1 (b)	<p>Paper 1: Subhashni Appanna, Alberto Bellocchi, James Davis</p> <p>Paper 2: Priscila Rebollo de Campos, Alberto Bellocchi, James Davis</p> <p>Paper 3: Tshewang Namgyel, Alberto Bellocchi, James Davis</p> <p>Paper 4: James Davis</p>	<p>Kathy Paige, Lisa O’Keeffe Primary pre-service teachers with an expertise in science and mathematics: perceptions of indigenous knowledges and practices and incorporation into transdisciplinary units of work</p>	<p>Amanda Berry, Jared Carpendale Unpacking Teachers’ Thinking and Practice of Integrated STEM</p>	<p>John Cripps Clark, Linda Hobbs, Seamus Delaney, George Aranda, Chris Speldewinde Devising a framework of innovation: Insights from evaluating the Victorian Tech Schools initiative</p>
Morning tea				
F2 (a)	<p>Rebecca Cooper, Jared Carpendale, Jennifer Mansfield, Karen Marangio Creativity and Critical Thinking in Secondary Science Pre-Service Teacher Education</p>	<p>Kai-Ming Kiang, Wai Man Szeto Teaching Traditional Chinese Science as a way of nurturing scientific literacy</p>	<p>Kyla Adams, Roshan Dattatri, Jyoti Kaurb, David Blair Ten years on: Impact of a Primary School Intervention on Aspects of Einsteinian Physics</p>	<p>Seungho Maeng Improving a science teacher’s epistemic teaching competence by implementation of ambitious science teaching practices</p>

F2 (b)	<p>Tabetha Spiteri, Amanda Berry, Rebecca Cooper, Jared Carpendale Primary School Girls' STEM Education Experiences – A Pilot Study</p>	<p>Ei Seul Kim, Hye Eun Chu, Hyeong Moon Lee, Jinwoong Song Investigating the impact of an intercultural STEAM program on group creativity</p>	<p>Bruce White, Lisa O’Keeffe, Melanie O’Leary Teaching Science through STEM inquiry projects</p>	<p>Sherab Tenzin, Mihye Won, David Treagust Student-generated Diagrams to Engage Students in Understanding Science Concepts</p>
F2 (c)	<p>Chloe Nelson, Jan van Driel, Victoria Millar Teachers' perceived benefits of interacting with science centres</p>	<p>Ha My (Anna) Mang, Hye-eun Chu, Sonya Martin, Chan-Jong Kim Theoretical approaches to an SSI-STEAM teaching: Developing and evaluating an SSI-STEAM program</p>	<p>Kathy Smith, Jennifer Mansfield, Deb Corrigan, Nicoleta Maynard, Amanday Berry, Peter Ellerton, Charlotte Pezaro, Shelley Waldon Understanding Problem Based Learning in school-based STEM education</p>	<p>Harry Lyndon, David Lloyd The enduring relevance of the Conceptual Mediation Program (CMP)</p>
Lunch				

Paper Abstracts

Ten years on: Impact of a Primary School Intervention on Aspects of Einsteinian Physics

*Kyla Adams, Roshan Dattatri, Supervisors: Jyoti Kaurb, David Blair
University of Western Australia*

Many students complete their compulsory science education without being taught modern physics concepts. In 2013 the first study of a modern physics teaching intervention conducted with an Australian upper primary school class was published. This intervention was the first step in challenging the paradigm of Newtonian teaching in schools. At the end of the first intervention, positive influences on participants attitudes towards the content was found. In 2020, 11 participants in the initial study (out of 26 total) were contacted for a follow-up questionnaire and interview to determine long-term effects. The results of the follow-up indicate that the intervention maintained a positive impression on participants. The models and analogies used during the six-week intervention were highly memorable. None of the respondents indicated feeling that they were too young to learn the concepts at the time. The participants found the interventions to be beneficial to their future learning. Even close to ten years after the intervention the participants remembered several key concepts and generally found no contradictions in concepts in future learning. The long-term follow-up of the intervention indicates that Einsteinian physics can be taught at the upper primary level and be recalled several years later.

Computational thinking, creative thinking

*George Aranda, Joseph Paul Ferguson
Deakin University*

Computational thinking (CT) is a form of problem-solving that can be enacted by a human or a computer agent. While creative thinking (CrT) is an essential part of CT, manifestations of CT do not generally take into account the creativity in developing such solutions. In this paper, we investigate the creative nature of CT in STEM by utilising the PISA competency model of CrT as students participate in a design-based task to construct a of game tic-tac-toe. We explore video excerpts in which primary students undertook unplugged programming (UP) activities and analyse, using micro-ethnographic methods, specific instances in which CrT and CT overlap. In particular, we unpack the specific aspects of CrT that are afforded by the hands-on nature of UP as a particular manifestation of CT. Our findings show that CT in the form of decomposition, abstraction, logical and algorithmic thinking provides opportunities for students to be creative as they generate diverse and novel ideas. We consider this research as contributing to ongoing efforts of the CT community to make clear what this approach adds to accounts of the creative nature of STEM, in particular for supporting teachers to identify and support the development of students' creative-computational thinking.

The level of green chemistry and sustainability awareness among pre- and in-service teachers in Israel, and their attitudes towards environmental education

*Ahmad Basheer, Naji Kortam, Ayshi Sindian
The Academic Arab College for Education in Israel- Haifa*

In this study, Israeli pre- and in-service science teachers were asked for their level of awareness about green chemistry, sustainability, and environmental education. Their views on the environment were also examined after the introduction of a unit on the chemistry of plastics. Out of 271 teachers who participated in the study, 123 of them were in-service science teachers with different seniority levels teaching in elementary, middle, and high schools and the remaining 148 were pre-service science teachers. The findings of the study showed that although teachers' views on environmental education are mostly positive, their sustainability and green chemistry awareness is low in general. Moreover, teachers' awareness about green chemistry and sustainability increases with the seniority levels. In-service science teachers were found to have more knowledge of green chemistry and sustainability than pre-service science teachers. After the intervention implemented for pre-service teachers (N=148), their level of green chemistry, sustainability, and environmental education awareness increased and their attitudes towards the environment became more positive. Also, pre-service teachers reported a high level of satisfaction with the intervention and noted that they will be more considerate about the environment around them.

Investigating the factors that foster and hinder understanding of physics concepts among prospective physics teachers

Lina Aviyanti, Carol Aldous, Penny Vandeur
Indonesia University of Education, Flinders University

This study sought to identify multiple variables that foster the understanding of physics concepts among Indonesian prospective physics teachers through quantitative studies. The relationships arising between these variables were examined using Structural Equation Modelling (SEM). Variables that were considered to hinder the improvement of prospective physics teachers' understanding of physics concepts were explored through semi-structured interviews. Five questionnaires were completed by a total of 706 participants, and 25 of these participants were interviewed individually. The results confirmed that the demographic factors of participants and their beliefs about the nature of knowledge and learning, as well as how they were able to argue and reason scientifically, affected positively their understanding of physics concepts. Furthermore, the study identified a number of factors that inhibited participants' enhancement in understanding physics concepts that related to their approaches to learning, the instructional media used, the nature of the classroom learning activities, the kind of learning assessments used, as well as the form of homework or assignments given in class. The findings of the study have the potential to contribute to the efforts of practitioners and policymakers wanting to improve the quality of physics teaching practices among Indonesian pre- and in-service teachers.

Unpacking Teachers' Thinking and Practice of Integrated STEM

Amanda Berry, Jared Carpendale

Monash University

This presentation explores how teachers with a commitment to teaching integrated STEM (i-STEM) perceive and implement such programmes. Integrated STEM education emerged from the idea that emphasising connections between the disciplinary components of STEM, along with making links to society and real world problems, can enhance student motivation and interest in STEM subjects. However, while there are many claims about the value of i-STEM, little is known about how teachers think about, and implement, i-STEM approaches within their schools and classrooms. In this study, 12 teachers from Victorian secondary schools with an explicit commitment to teaching i-STEM were interviewed about their views about i-STEM, along with the issues and challenges that they encountered when designing and implementing i-STEM approaches. Preliminary findings indicate that most teachers are implementing these approaches with little support and were concerned about doing i-STEM 'the right way'. At the same time, they considered i-STEM as more engaging than traditional science and mathematics classes, and when students worked in groups to respond to real-world problems, those tasks fostered key thinking skills such as creativity and problem solving. However, participants rarely considered the curriculum outside of their own STEM discipline when planning or developing assessment tasks.

A genealogical study interrogating the STEM education agenda in Australia

Jeff Brown, Supervisors: Karen Murcia, Brad Gobby

Curtin University

In Western liberal democracies, political authorities charge themselves with responsibility for securing the state and its population. In contemporary neoliberal states like Australia, facilitating national and individual economic competitiveness is one condition of security and the institution of education is one instrument through which these ends are pursued.

Australia, like other western democracies, has literacy, mathematics and science as high priorities in education, however, it has become clear that an additional Science, Technology, Engineering and Mathematics (STEM) agenda is also well upon us.

This paper presents a beginning genealogy of the discourses, and events that have led to the emergence of the STEM education agenda as a curriculum priority in Australia. Informed by a Foucauldian theoretical perspective and Actor Network Theory, the emergence and shaping of 'STEM Education' is analysed through its articulation in key documents and artefacts.

Looking to history to explain the present, the study casts a light over the relationship of STEM to the biopolitical aims of government by mapping political, social and governmental relations, events and power-knowledge claims that are the conditions of the agenda.

There is no such genealogy in the literature specific to the STEM agenda, therefore this study fills this gap in knowledge and will shed some light on the processes of governmentality in agenda formation. The research will provide background information to stakeholders, inform policy makers, and offer directions for further studies.

Investigating students' views of their science capability development

Cathy Bunting, Dayle Anderson, Dianne Christenson[#]*

*University of Waikato, * Victoria University of Wellington, [#]Koraunui School*

In New Zealand, five science capabilities have been identified in order to support teachers to help students develop a functional knowledge of the nature of science. They are: gather and interpret data, use evidence, critique evidence, interpret representations, and engage with science. As part of a three-year research project investigating the use of online citizen science projects in school science programmes, we needed to develop methods to assess students' science capability development. This presentation will focus on our use of conversation prompts with student focus groups. We'll also share examples that demonstrate how key features of the online citizen projects and classroom programmes seem to have contributed to students' perceptions of what they had learned to be able to do.

Research-informed frameworks to support teacher professional learning and school change in STEM

*Coral Campbell, Lihua Xu, Linda Hobbs
Deakin University*

With the recent endorsement of STEM education as part of the *National Innovation and Science Agenda* by the Australian Government, the challenge facing educators is how to meaningfully embed STEM-related knowledge, skills, and dispositions in all levels of schooling. Educators and researchers are becoming increasingly interested in investigating contexts that support students' learning in STEM and what teaching approaches are most conducive for developing problem-solving, reasoning and design skills. Such debate and consideration of the value of STEM in education acknowledges a proliferation of multiple understandings of STEM education and the emerging diversity of approaches to STEM teaching. This presentation reports on teachers from primary schools in regional Victoria who were involved in a professional learning program specifically designed to build their confidence and capacity for teaching STEM through inquiry-based approaches. Frameworks relating to STEM curriculum development and teacher and school change provided structure and focus for the program. Data of changing teacher STEM pedagogy provide insight into the diverse responses that schools can have to professional learning. The findings of the study indicate the importance of research-informed frameworks that are flexible enough to be applied to schools at different stages of STEM implementation.

School science – Thoughts on an approach to rethinking what students learn and how they might be better engaged

*Connie Cirkony, Glykeria Fragkiadaki, Richard Gunstone
Monash University*

Diverse science curriculum movements have provided different conceptualisations about the science content students should learn and suggested several pedagogical practices to engage students in science learning. However, identifying what is meaningful for the students to learn during their formal school education and keeping students engaged in science over time

remains an ongoing challenge. This presentation aims at discussing three quite diverse broad areas of scholarship relevant to school science to provide insights around this challenge. Three broad areas are discussed in turn: a) the concept of imagination and creativity through cultural-historical approaches of early science learning; b) the relatively long-standing support for inquiry-based approaches; and c) the Northern European constructs of *Didakik* and *Bildung* as possible paths to having school curriculum respond to the problematic dimensions of science content. We argue that this discussion can lead to approaches that address challenges in a way to promote threads that orient around the ‘big ideas’ (Harlen et al., 2010) of science fundamental to the learner over the course of their education.

Embedding critical and creative thinking in the lower secondary science curriculum: challenges and opportunities

*Leana Coleman, Supervisors: Kathy Paige, Graham Hardy
University of South Australia*

Curriculum policy makers acknowledge that critical and creative thinking (CCT) are vital twenty-first century skills, not only to meet future workforce demands but to enhance the personal and social well-being of all (Vincent-Lancrin et al, 2019). The Australian Curriculum, Assessment and Reporting Authority have outlined Critical and Creative Thinking among the General Capabilities students are to develop in all learning areas, including Science. But achieving this in an era of standardisation and crowded curricula, within the constraints of the secondary school ecosystem, makes this an effortful - even countercultural - pursuit.

This exploratory case study examined the practice of nine exemplary science teachers, working in a range of secondary school contexts in South Australia as they embedded opportunities for CCT in Year 8 – 10 science curricula. Science lessons were observed over the course of a 5-week unit and interviews were conducted with teachers and student focus groups.

As well as showcasing the diversity of opportunities for students to engage in CCT, this paper also reports where tasks rich in potential for CCT were not embraced by students as intended. The enabling factors as well as the challenges for teachers for enacting a CCT-rich curriculum in science will be presented, and ways that teachers, schools and policymakers can address these issues will be considered.

Vincent-Lancrin, S et al. 2019, *Fostering Students' Creativity and Critical Thinking: What it Means in School*, Educational Research and Innovation, OECD Publishing, Paris, <https://doi.org/10.1787/62212c37-en>.

Technology as integrator in STEM – co-curation and co-creation

*Lindsey Conner
Flinders University*

The enthusiasm and “hype” for integrating STEM have not necessarily examined research on how using technologies can support co-curation and co-creation of new knowledge. The aim of this research was to elucidate effective technologies that act as enablers for integrating

STEM. The synthetic literature review on increasingly sophisticated inclusion of technologies for learning in STEM contexts, produced evidence about applying technologies within problem-solving, inquiry and challenge activities as these augment the means to develop specialist knowledge, technical and generic skills and capabilities simultaneously. This includes accessing information, designing visual representations of data, refining and evaluating techniques, collaborating and communicating using technologies that also make it quicker to sort, navigate and co-create new knowledge as part of problem-solving local and global issues. The research revealed examples of STEM curriculum implementation that enabled creative innovation and the ability to connect virtually to make use of learning networks for co-curation and co-creation.

Creativity and Critical Thinking in Secondary Science Pre-Service Teacher Education

*Rebecca Cooper, Jared Carpendale, Jennifer Mansfield, Karen Marangio
Monash University*

One of Monash University graduate attributes is to prepare graduates who are critical and creative scholars. Coupled with the rise in creativity and critical thinking as aspects of learning and teaching, the secondary science education team at Monash University investigated how having a greater emphasis on the explicit articulation of creativity and critical thinking in their teaching and assessment with pre-service science teachers would influence their own thinking about creativity and critical thinking. Four (authors) secondary science educators participated in this reflective study over two semesters. Data were collected in the form of curriculum and planning documents, meeting notes, meeting recordings, reflective journal entries. An inductive thematic analysis was conducted looking for emergent common themes. Findings signal that while aspects of creativity and critical thinking were identifiable in units and assessment items to the educators, the challenge came in articulating this clearly to pre-service teachers. However, with this clarification and articulation came a further tension where explication led to oversimplification. Further, there was a sense that pre-service teachers may interpret creativity and critical thinking as freedom and limitless possibilities, thus foregoing appropriateness and suitability in order to embrace creativity and critical thinking.

Devising a framework of innovation: Insights from evaluating the Victorian Tech Schools initiative

*John Cripps Clark, Linda Hobbs, Seamus Delaney, George Aranda, Chris Speldewinde
Deakin University*

STEM (Science, Technology, Engineering and Mathematics) education is positioned as critical to achieving a STEM literate workforce and society. Evaluations of STEM-focused initiatives are needed that focus on the nature of innovation arising and the conditions that are needed to create this innovation. This presentation draws on insights about innovation from an evaluation of the Victorian Department of Education and Training's Tech Schools Initiative. Drawing on Jäger's (2004) wave model of innovation, an Innovation Framework focusing on content, structure and people was developed and is being used alongside an

evaluation framework to underpin an Impact analysis (focusing on the outcomes) and an Ecosystem analysis (focusing on the conditions needed for innovation to occur). Seven categories of innovation have emerged from analysis of interviews with Tech School staff, industry partners and host representatives. The categories highlight the innovative nature of the Tech Schools, the products of innovation emerging and expected, and critical success factors that will inform the ongoing evaluation. This theorisation of innovation extends our understanding of: the nature of innovation at STEM learning centres; innovative approaches to STEM education; the conditions needed for innovation to arise; and what might be transferable to other similar initiatives.

A multi-country comparison of climate change curricula in secondary school

Vaille Dawson, University of Western Australia

Efrat Eilam, Victoria University

Peta White, Deakin University

Agung Wijaya Subiantoro, Universitas Negeri Yogyakarta, Indonesia

Daphne Goldman, Tel Aviv University, Beit Berl College, Israel

Gusti Agung Paramitha Eka Putri, Victoria University

Helen Widdop Quinton, Victoria University

Orit Ben Zvi Assaraf, Ben-Gurion University of the Negev, Israel

Rishi Krishnamoorthy, New York University, USA

Sakari Tolppanen, University of East Finland, Finland

Tuba Gokpinar, University College London, England

There is little doubt that humanity is facing a critical time in its history. The combined challenges of COVID-19 and climate change mean that science education research is more important than ever in preparing young people for an uncertain future. The focus of this research is climate change education and its status in the compulsory years of secondary school across seven countries (Australia, Canada, Finland, Indonesia, Israel, UK, and the US). The authors used document analysis to interrogate formal school curriculum documents, specifically science and geography to determine the presence of climate change topics and the way they are addressed in these core subjects. The key findings are that: (1) the term ‘climate change’ appears in the formal curriculum of all seven countries in science and/or geography; (2) climate change is more likely to be presented as a context, example, or elaboration for other science skills than a discrete topic studied via a holistic approach; and (3) climate change education is sparse and spread over multiple years. This raises questions as to whether current school curricula can develop competencies for responsible, informed, and ethical decision-making regarding actions that impact climate.

Establishing a chemistry education research-oriented professional learning community with teachers through co-design methodology

Seamus Delaney

Deakin University

Tangible benefits of science education innovation risk not being realised unless teachers and practitioners are meaningfully involved. Design-based research has been proposed as a means

to develop and refine interventions whilst keeping the theory and practice relationship at the forefront for all involved. This paper presents on an ongoing professional learning communities project, which has the research aim to inform on and support secondary chemistry teachers to implement different aspects of chemistry education research (CER) in their teaching. After initial workshops, groups of teachers are co-supported to develop and implement a CER-informed research project in their schools. They evaluate their intervention by collecting evidence ethically from students, before presenting their findings (in teacher conferences, professional magazines) which encourages them to contribute back to the larger teaching community.

In 2020, two groups of teachers completed this cycle, one focussing on explicit teaching strategies supporting chemistry literacy development, and another on situating sustainable development in the chemistry classroom through systems thinking. This paper reports on evidence collected from the teachers involved, acknowledging their importance in the co-design research process, including pre- and post-surveys, artefacts and semi structured interviews, that has helped framed the involvement of future cohorts of teachers in the project.

The Benefits of Establishing a Climate Change Subject in the Curriculum

Efrat Eilam

Victoria University

Climate change (CC) is commonly addressed in school curriculum through a cross-curriculum approach in which it is subsumed under various disciplinary-subjects. This framework of inclusion causes fragmentation and undermines the integrity of the field, posing challenges to teaching and learning. Here I make a case for including CC in the curriculum as a disciplinary-subject in its own right. The term *discipline* is understood as specialised knowledge in both structure and purpose. *Subject* is understood as the selection and organisation of disciplinary-knowledge for delivery. Disciplines emerge and morph as knowledge grows. The field of CC has been establishing itself incrementally over decades. Some concepts in CC can only be understood through disciplinary merges, where each of the disciplines-of-origin on its own is unable to provide a comprehensive explanation to CC problems. By establishing an independent CC-subject in the curriculum, multiple benefits will be gained, including: Enhancing the status of CC in the curriculum hierarchy, allocation of time and space in the school timetable, categories of examination, and accreditation, supporting the development of CC teacher professional identity, and inducting students into the discipline through the acquisition of skills, concepts and rules required for learning and working within the CC disciplinary space.

Teaching the nature of science through an understanding of argument structure

Peter Ellerton

University of Queensland

There is a significant body of literature showing the value of linking science and argumentation to improving student outcomes. Less explored is how students can better understand the nature of science itself by examining the connection between argumentation

and the methodology of science as a form of inquiry. This paper will discuss how the key concepts of science, including laws, theories, proof and falsifiability, are developed from basic concepts of argument types and structure. Analysing scientific methodologies through the lens of argumentation can help students understand and justify the epistemic credibility of science, explain its limitations and misapplication, and ground it philosophically as a rational endeavour. This represents an important aspect of scientific literacy that goes beyond simply understanding scientific theories and knowing facts about the world.

Three case studies: valuing science in the middle school – students, teachers and parents

*Katrina Elliott, Kathy Paige
University of South Australia*

Whilst there is much research highlighting teachers' reasons for valuing science and why it should be valued, there is less about what factors influence students' valuing of science. In the middle school only 8.6% students consistently expressed science-related career aspirations (Sheldrake, 2018). The aim of this study is to find out what factors contribute to those students who value science and are engaged in learning science, in order to be able to suggest changes in pedagogical practices. The purpose of my research is to work in the space/intersection between parents, students and teachers and their impact on students valuing and identifying with science (Halim et al 2018). Three case studies of Year 8 classrooms have been used to determine how students' values and identities are impacted on by their teachers' pedagogical practices, parents' value of learning science and social media (Yin 2003). The instruments used for data collection were classroom observation, semi structured interviews with 6 Year 8 science teachers and 18 students. In addition students were asked to bring along an artefact that represented their value of science and how they identify with learning science (Pahl & Rowsell, 2019).

School strikers enacting politics for the environment – Daring to think differently about science and environmental education

*Joseph Ferguson, Peta White
Deakin University*

Two school strikers join two environmental education academics to explore what it means to be young people enacting politics for the environment in Australia. Niamh and Harriet are leaders of, and were integral to initiating, the highly effective *School Strike 4 Climate - Australia (SS4C)* movement. Joseph and Peta work in teacher education, preparing future teachers who will teach students who are increasingly climate savvy and politically active. To undertake this research *with* Niamh and Harriet as genuine co-researchers and co-writers, we needed to push back against institutional ethics protocols. The research was deemed not low risk due to the political focus and it was also nearly not approved as higher-than-low-risk due to the age of the school striker leaders. We highlight, through the lens of pragmatism and collaborative autoethnography, the political nature of what Niamh and Harriet have been undertaking as they negotiate social, cultural, educational and environmental issues implicated in the climate crisis. Through Niamh's and Harriet's experiences, we explore how young people express agency while developing identity. We highlight the changing nature of

our student body demonstrated by Niamh's and Harriet's stories and call for us all to 'dare to think' differently about science and environmental education.

The push or the pull? Investigating tensions and possibilities in two science teacher educators' return to schools

*Angela Fitzgerald- University of Southern Queensland and Mirboo North Secondary College
Kimberley Pressick-Kilborn - University of Technology Sydney and Newington College*

In science education in Australia and internationally, there are many teacher educators who regularly engage in ongoing work with primary and secondary students through University-School partnership initiatives. There also is a precedent of science education researchers who have returned to school-based classroom teaching roles for sabbatical blocks. In the research literature, it is more difficult to locate studies of teacher educators who have resigned their tenure to return to school-based positions in 2021. In this paper, we draw on research methodologies including self-study, autoethnography and narrative inquiry to begin to investigate tensions and possibilities in our own return to school roles in 2021. While the data collection is in its early stages, some emergent themes include: notions of being an experienced rookie, questioning sense of identity, and navigating the tensions posed by being an educational insider-outsider in a school-based setting. This research is important as it provides very direct insights into the lived realities of the contemporary classroom and how this is juxtapositioned against the experiences provided in initial teacher education to nurture classroom ready graduates. It is anticipated that this study will lead to lively discussion about the ways in which schools and universities can more productively work together.

Citizen science in the Lab: Exploring unique learning experiences

*Yaëla Golumbic, Alice Motion
School of Chemistry, Sydney University*

Citizen science is a growing field of research and practice, in which volunteers engage in active scientific research. Participation in citizen science provides many learning opportunities and has shown to promote scientific literacy, critical thinking and social and environmental awareness. However, how this learning takes place, what factors are involved in this process and how to best promote learning through citizen science, are not well understood. In this paper, we aim to investigate the learning processes and outcomes of first year university students participating in the *Breaking Good* citizen science initiative as part of their first-year lab instruction.

Breaking Good engages students in the synthesis of brand-new molecules, contributing to ongoing drug discovery. Using interviews, questionnaires and guided conversations we illustrate a unique project environment, facilitating broad learning experiences and outcomes. Students describe the authentic nature of *Breaking Good*, and its impactful vision as a mediator of learning, and the hands-on lab experience as promoting this process. Learning outcomes include content, process and Nature of Science knowledge, elevated scientific skills and transfer of learning to daily life.

These results highlight the potential of citizen science to contribute to high-level learning and provide guidelines for future student engagement in citizen science.

Assessment of science learning in early childhood: What influences teachers' assessment practice?

*Christina Guarrella, Supervisors: Jan van Driel, Caroline Cohrssen**
*The University of Melbourne, *The University of Hong Kong*

Australia's science and innovation agenda has led to a multitude of science and STEM education strategies at the state level. In the Northern Territory (NT) of Australia, one such strategy was designed with preschool teachers in response to their calls for support to incorporate science in emergent early childhood curricula. One component of a suite of STEM curriculum resources, the 'NT Preschool Science Games' supports high quality pedagogy and children's engagement in meaningful scientific experiences.

This presentation will examine the assessment practices of three teachers who participated in targeted professional learning aligned with the roll out of the NT Preschool Science Games. Included in the professional learning was a tailored, online platform designed to facilitate teacher assessment of science process skills. The teachers' use of this assessment instrument will be qualitatively analysed to understand how teachers enact the Early Years Planning Cycle to assess science process skills in daily teaching practice. Further, thematic analysis of semi-structured interviews will illuminate the influences on teachers' science assessment practices during their introduction to, and ongoing use of, the NT Preschool Science Games. Implications for early childhood assessment and planning models, teaching practice and policy will be discussed.

Female elementary student's social construction of epistemic emotions: Effects on her patterns of participation in small-group scientific argumentation and modelling

*Sally B. Gutierrez, Moonhyun Han**
*University of the Philippines, *Seoul National University of Education*

This qualitative single-case study explored how a female student's socially constructed emotions affected her patterns of participation in the six lessons that comprised the small group scientific argumentation and modeling of the human respiratory system. Various data such as emotion diaries, transcripts of the video recordings, post-lesson interviews, and field notes were analyzed through constant comparison method. Iterative analyses were done to explore how she constructed the epistemic emotions of *frustration*, *anxiety*, and *joy* and how these emotions facilitated the patterns of her participation in their small group scientific argumentation and modeling of the human respiratory system. She constructed *frustration* in Lesson 1 because of her difficulty in constructing claims with evidence and this facilitated her non-participation. In Lessons 2 and 3, she constructed *anxiety* because of her uncertainty in her opinions. However, despite being anxious, she was able to contribute passively with elicited responses. Finally, she constructed epistemic *joy* which facilitated her active participation in Lessons 5 and 6 after gaining familiarity on how to engage in scientific argumentation and appreciating the advantages of scientific modeling to understand the abstract concepts of the human respiratory system.

Criteria for Evaluating Climate Change Models of Preservice Earth Science Teachers

*Yoon-Hee Ha, Hyeonjeong Shin, Hyun-jung Cha, Supervisor: Chan-jong Kim
Seoul National University*

This study aims to explore the criteria that preservice teachers use to evaluate the climate change model constructed by students. The participants are 21 undergraduate students who major in earth science education. Preservice teachers learned the definition of a model, type of models, modeling, model-based learning in a major course. They also performed a task evaluating the 'climate change model' that high school students constructed in the modeling learning activity as a part of climate change club activities. In this study, we analyzed the report on climate change model evaluation written by the preservice teachers and conducted interviews. The data were categorized through open coding. It reveals that curriculum and epistemological criteria are used dominantly. Many preservice teachers used epistemological criteria to evaluate the interconnectivity between each factor of the Earth system. Some preservice teachers considered whether it is consistent with the science curriculum. Compared to prior studies, it was found that preservice teachers sometimes use different criteria than the evaluation criteria that students use when evaluating models. The findings are expected to provide the implication of model-based climate change education and give the information of teacher's perceptions of the climate change model and model evaluation.

Analysis of Instructional Designs for Promoting Inquiry Practices in the Physics Curriculum Standard Documents and Textbooks

*Suarman Halawa, Ying-Shao Hsu (supervisor), Wen-Xin Zhang
National Taiwan Normal University*

This study explores textbook instructional designs for promoting inquiry practices and expected outcomes in physics curriculum standards at the secondary level. Three criteria were employed to select textbooks: (1) approved by the Ministry of Education of Singapore and the Ministry of Education and Culture of Indonesia, (2) mostly used at the secondary level, (3) included physics content and practices based on the curriculum standards. We selected two textbooks from Singapore and three from Indonesia for analysis of learning goals, consistency with national curriculum standards, inquiry skills, understanding of inquiry, and inquiry types. Results showed that the Singaporean curriculum standards explicitly exhibit inquiry skills for each type of physics content (defining, identifying, using formulations, constructing models, interpreting data to construct conceptual understanding). Most inquiry activities are structured inquiry (64.7%), providing few opportunities for students to understand the inquiry. Activities in the Singaporean textbooks engage students in reflecting on investigations (100%), but few expect students to communicate their results. Contrarily, inquiry activities in the Indonesian textbooks expect students to communicate or present results of experiments (23%) but do not engage them in reflection. Findings indicate that the textbook inquiry practices were not designed to include all features of inquiry practices.

Keywords: Scientific inquiry, learning goals, inquiry skills, textbook analysis.

Emotional responses of middle years students when writing two different Biostories using computers

*Senka Henderson, Donna King**

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While a significant body of research states that practical work, such as laboratory activities, discrepant events and demonstrations are regarded as highly interesting and seen favourably by students in science classes, there is less research about the computer-based activities that evoke interest and emotional responses. In the current study, we present the case study of year 8 students during two school terms when writing Biostories to show how the emotional responses were aroused during the computer-based activities when students were writing about two different Socioscientific issues. The two topics were Coal Seam Gas (CSG) mining and Singed which focussed on the biology of skin burns. Through an ethnographic case study method, we have collected and analysed data including video recordings, observations of the classroom, thinking prompts, interviews, field notes and emotion diaries completed at the end of each lesson. Three themes emerged. First, students' reported interest was higher on average for the topics of Singed compared to CSG mining. Second, students expressed positive emotions and interest in computer-based classes for both topics, however when the interest scores for computer-based lessons for both topics have been compared, there was a greater average interest for Singed compared to CSG. Third, as reported on the thinking prompts, students' responses to questions about the moral and ethical dilemmas associated with CSG mining and Singed increased in frequency and variety as the term progressed, however, there was a greater increase in the CSG topic. Finally, we provide reasons for the students' heightened interest and more favourable experiences during computer-based lessons.

Key words: Topic, SSI, Computers, Emotional responses, Middle school science

Developing an understanding and model of Australian student wellbeing in science education

*Julia Hill, Supervisors: Jan van Driel, Wee Tiong Seah, Margaret L Kearns
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Complementing the traditional focus on achievement, schools are increasingly striving to support students' holistic development, including wellbeing, defined as how students feel and function across different dimensions (e.g., mentally, socially, cognitively). Despite much interest in general student wellbeing, wellbeing within individual subjects – such as science – is under-researched. Students often perceive science as irrelevant and boring, are disengaged with their classes, and express negative attitudes and emotions about the scientific topics. Achievement in international science assessments continues to decline for Australian students, further indicating low student wellbeing specific to science education. This paper explores the perspectives of 321 Australian Year 8 students to understand factors supporting science wellbeing. Students freely responded to the question: *What makes you feel really good and/or function well in science?* Responses were analysed using a combined deductive/inductive thematic analysis approach. Results support a seven-dimensional model of student science wellbeing, with engagement mentioned most frequently, then relationships,

positive emotions, cognitions, accomplishments, meaning, and perseverance. This study illustrates the importance of focusing on student wellbeing within individual subjects and provides a model of relevant domains for understanding and building student wellbeing in science education in the future.

Experiencing Online Learning During Global Pandemic COVID-19: A Study in Health Education

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*STIKes Kusuma Bangsa Nusa Tenggara Barat, * Universitas Nahdlatul Ulama Nusa Tenggara Barat, # University of South Australia*

Online learning in Indonesia encounters several obstacles, i.e., internet stability, limited quotas, and access to the internet. This is worsened as the device is scarce and internet stability becomes major issues especially in a remote area. Another problem is the issue of new poverty in various corners of the region due to the impact of global pandemic COVID-19. This study explores the experiences, constraints, challenges, and strategies carried out by lecturers in carrying out online learning in health education. This research applies Social Stigmatization Theory and case studies through qualitative approaches. Observation and FGD were conducted by involving three health institutions in NTB Province. The study finds that due to the vulnerabilities of the students, the stigma in using sensible and responsible language are significant issues found among lecturers. The challenge is how to maintain students' engagement in online learning delivery using a blended learning approach. The global pandemic provides a vast opportunity for lecturers and students to innovate further. The use of robotic practicum enhances students' competencies in remote laboratory practicum. The study finds safe and sensible practices in using shared facilities in the laboratory for practicum purposes, by managing the number of participants in the laboratory, managing schedules, and maintaining disinfection properly.

Keywords: Online Learning Delivery, COVID-19, Stigma in Language, Students' Engagement, Shared Facilities, Robotic Practicum.

Criteria for defining teaching out-of-field: Representing a complex phenomenon

*Linda Hobbs
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Teaching out-of-field generally refers to misalignment between what a teacher teaches and their qualifications and background. Because of state, national and international differences in teacher registration, approval and certification, there is no single definition of what makes a teacher in- or out-of-field. Also, realities on the ground often mean that 'suitably' to teach a subject is determined by criteria other than qualifications. Also, science teachers can be in-field but feel out-of-field teaching some science disciplines. Representing this complex phenomenon through a single definition fails to capture the complex reasons teachers are or 'feel' out-of-field, and the potential responses that are needed to attend to this issue. In this paper we report on a study contracted by the Victorian Department of Education and Training (DET) where we used a systematic literature review and interviews with key informants to

develop six research-informed criteria to determine out-of-field-ness; these criteria are categorised as Measurable (1.Qualification, 2.Workload and 3.Capability), Self-report (4.Identity and 5.Structures), or Longitudinal (6.Pathways). Four definitions were derived from these categories. This approach to defining teaching out-of-field enables the criteria to foreground different aspects of the phenomenon and position different stakeholders as being part of both determining how teachers experience out-of-field-ness and movement towards in-field-ness.

Factors Predicting the Science Teaching Practices of Kindergarten Teachers in Indigenous Areas in Taiwan

*Ching-Ting Hsin, Hsin-Kai Wu, Jyh-Chong Liang
National Taiwan Normal University, Taiwan*

Past studies have found that kindergarten teachers had low science teaching self-efficacy and rarely taught science. Additionally, when compared with non-Indigenous children, Indigenous children had low achievement and participation in science. Our research aims to establish a model to understand the associations between kindergarten teachers' science teaching self-efficacy, their outcome expectations for students, and their teaching practices in science. Also, it examined how other factors (e.g., mastery experience, perceived contextual support, attitude toward minority groups, and attitude about multicultural teaching) predict teachers' self-efficacy and outcome expectations. Partial least square structural equation modeling (PLS-SEM) was employed to analyse 384 valid questionnaires from private and public kindergarten teachers in indigenous areas of Taiwan, teaching children aged 4-6. The results showed that science teaching self-efficacy was the unique positive predictor for the teachers' science teaching practices. Moreover, three factors significantly and positively predicted teachers' science teaching self-efficacy: teachers' mastery experience; perceived contextual support; and attitude about multicultural teaching. Finally we found that four factors significantly and positively predicted teachers' outcome expectations for their students: teachers' self-efficacy; perceived contextual support; attitude toward minority groups; and attitude about multicultural teaching.

Why perceptions of ecological stimuli shape students' SSI learning interest and enjoyment

*Brady Jack
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This qualitative investigation explores students' interest and enjoyment derived from learning socio-scientific issues (SSI). In this study a small group of 15-year-old students (N=25) are selected and interviewed regarding personal beliefs of about three discrete ecological stimuli (textbooks, media news [MN], and *family* [i.e., family and friends]) either positively or negatively affect their SSI learning interest and enjoyment. The significance of this investigation is that it opens an opportunity for students to not only examine their own perceptions about what makes learning SSI interesting and enjoyable personally, but also allows them to equally voice their perspectives on what does not make learning SSI interesting and enjoyable. Data collected from students located at three separate high schools

in southern Taiwan using a one-on-one interview protocol especially designed for this study were examined to answer a single two-tiered research question: Why do student perceptions of textbooks, MN, and family affect their SSI learning interest and enjoyment? Results show greater impact of MN on students' interest and enjoyment learning SSI, and textbooks of greater impact than family. Reasons for these results as expressed by these students, and why the findings of this investigation may be of importance to science educators, are forwarded.

Multimodal Creative Inquiry: theorising a new approach for children's science meaning making in early childhood education

Sarika Kewalramani, Nikolai Veresov
Monash University

With technology becoming the mediator of children's everyday contexts, there have been very few studies which consider the multimodal nature of technologies to act as semiotic tools for enabling children's sense making of everyday scientific phenomena. This paper explores how by using technologies such as robotic toys, multimodal creative inquiry might be conceptualised and implemented for children's meaning making in science. We consider Halliday's (1978) and Vygotsky's (1987, 2016) theoretical ideas for showing how the most important characteristics of social semiotics are connected to imagination, play-based and creative inquiry for children's science meaning making. Qualitative data was analysed from two preschool classroom video observations of 40 children's playful interactions with technologies, such as robotic toys, two teachers' reflective journal documentation and children's drawings and constructions. Findings show children participate and discuss elements of scientific concepts in inquiry-based dialogues and make sense of science concepts whilst becoming creators of multimodal representations arising from their interests and curiosity. The robotic toys that operate through Apps provide a medium for creative inquiry affording communication spaces through multiple modes (visual, digital touch, movement), fostering children's meaning making of everyday science phenomena. Practical implications lie in upskilling educators' integration of robotic toys as a semiotic resource and deploying a multimodal creative inquiry approach for reconfiguring children's science learning opportunities in early childhood educational practices.

Keywords: creative inquiry approach, children's science meaning making, early childhood science, multimodal semiotic resource, Vygotsky and Halliday integrated theoretical model

Forming an understanding of students' attitudes towards school Science

John Kennedy, Simon Leonard
University of South Australia

Much research over the last decade has warned of decreasing enrolments in and engagement with school science. Consequently, many programs have been developed with the aim of improving student attitudes towards the subject. However, student attitudes towards science are both multi-faceted and liable. This paper reports some of the initial findings from a longitudinal study at a South Australian school. Using the School Attitude Survey, we collected data from 866 students in Years 6 to 12 and this paper examines some of the

students' attitude trajectories towards science over the first year of data collection. Text mining and sentiment analysis were used to examine students' explanations for their attitude ratings and some emerging patterns are discussed. We found that students' intentions towards further study were most highly correlated with their perceived relevance and usefulness of school science. Furthermore, their ratings of enjoyability were strongly related to feelings of self-efficacy and lack of subject anxiety. Both positive and negative longitudinal trends in attitudes are evident and these are related to the students' gender and their age. Finally, we found that students' positive explanations tended to use emotive words related to student action, while their negative explanations referred to content and assessment.

Exploring participant engagement during an astrophysics virtual reality experience at a science festival

Magdalena Kersting, Rolf Steier, Grady Venville#*

*University of Oslo, *Oslo Metropolitan University, #Australian National University*

Virtual reality applications turn abstract concepts into experienceable phenomena and present exciting opportunities to transform science education and public outreach practices. While research has started to look into the affordances of virtual reality (VR) in the formal science education context, the potential of these technologies to enhance public engagement with science is largely unexplored. To improve the way that VR may be used in informal learning and public outreach contexts, the purpose of our study was to undertake evidence-based investigations that explore the relationship between VR and public engagement. Aiming to identify and develop the benefits of VR technologies, we propose a conceptual framework for engagement with VR at a science festival that comprises four aspects of participant activity: *immersion, facilitation, collaboration, and visualisation*. This framework guided the research design of our exploratory case study of one VR tour at a science festival. Data included visitor surveys, video recordings, VR screen captures, and focus group interviews with outreach and science professionals. Our findings reveal important ways that VR supports visitor engagement at a science festival. More generally, these findings and our framework contribute to the ongoing efforts of engaging the public with science in more diverse informal learning contexts.

Teaching Traditional Chinese Science as a way of nurturing scientific literacy

Kai-Ming Kiang, Wai Man Szeto

The Chinese University of Hong Kong, Hong Kong

Whether Traditional Chinese Science can be considered as a true science has often been debated in the academic circle. In the eye of the public, however, it is often accepted as an alternative science, especially in Chinese society. For science educators, approaching Traditional Chinese Science as pseudoscience without any open discussion, in general, could easily stimulate students' resistance, which could be counterproductive. In this presentation, we suggest using Traditional Chinese Science as a starting point to engage students to debate and ponder upon the meaning of science. This could allow better integration of the nature of science with ones' culture and prior knowledge. This approach was adopted in a general

education course in a Hong Kong university that aims to nurture scientific literacy. Through analyzing the class discussions and term papers from this course, the result showed that teaching Traditional Chinese Science could effectively arouse students' interest, as well as enable them to reflect on the meaning of science in a more socially and culturally embedded way. We believe that our approach can be considered as a reference case for other science educators to design their courses.

Investigating the impact of an intercultural STEAM program on group creativity

Ei Seul Kim, Hye Eun Chu, Hyeong Moon Lee, Supervisor: Jinwoong Song
Seoul National University, * Macquarie University*

During the COVID-19 lockdowns, Korean schools developed various ICT network systems to deliver science teaching online. This helped schools pursue online intercultural interactions. Thus, this study explored the impact of the online intercultural STEAM program on students' group creativity in science classrooms. We developed eight lessons on the topic of 'The zero-energy house' which were introduced into science classrooms in Korea (Anyang) and Australia (Sydney) asynchronously. Hong's (2016) Science Classroom Creativity (SCC) questionnaire was modified to 60 questions to examine the group creativity of 27 Korean Year 10 students. The questionnaire was implemented before and after the application of the intercultural STEAM program and 11 Korean students participated in in-depth interviews afterwards. The classroom artefacts and the students' comments posted on an online bulletin board were also collected and analyzed. Of the many components under group creativity, our findings demonstrated both quantitative and qualitative improvements in cognitive and affective areas and significantly higher response levels in active class engagement and creative behavior. The interview and artefacts analyses, including students' thinking processes and solutions on the zero-energy house, will be shared during the presentation.

The Effect of Simulation-based Biology Teaching on Students' Achievement and Attitudes toward Science

*Naji Kortam, Ahmad Basheer, Nibal Barbara
Academic Arab College of Education Haifa, Israel*

Simulations are teaching tools that have many benefits such as teaching improvement, facilitating learning, and developing important skills. This study examines the effectiveness of teaching biology of the cell with simulations and its influence on the students' achievement and attitudes towards science. Participants of this pretest-posttest quasi experimental research included 102 middle school students from four 9th grade who studied the teaching unit "Cell Structure and Function". The experimental group studied the subject with a simulation-based teaching approach, while the control group studied it with a traditional teaching approach. Mixed methods design was utilized. The research data were collected via pre and post achievement tests and a questionnaire regarding the students' attitudes toward science. In addition, interviews were utilized to find out the applicability of simulation-based teaching into biology of the cell. The findings showed that the simulation-based teaching approach led to a statistically significant increase in the experimental students' achievement, and significant

difference in the students' attitudes towards science, than those of the control group. The interviews revealed that students stated enjoyment, interest, satisfaction, and greater understanding of complex topics. In light of these findings, it could be stated that it will be beneficial to increase incorporating this teaching-learning strategy in teaching biology.

The enduring relevance of the Conceptual Mediation Program (CMP)

Harry Lyndon, David Lloyd

A meta-study of 86 different models of conceptual change in the domain of science education [Potvin et al (2020)] demonstrates that there has been an overt emphasis in this research on epistemological perspectives. Only one project reviewed focussed directly on the psychological causes and resolution of the learning difficulties experienced by science students that being the Conceptual Mediation Program. The CMP was a decade long research project conducted in Australian secondary schools. A review and report on the successful outcomes of this interdisciplinary project has been published (Yates and Lyndon, 2004). The theoretical perspective (Lyndon, 2000) proposed that the well-documented learning difficulties experienced by science students arise as an outcome of the natural tendency of the mind to conserve prior learning in the face of conflicting new experience. It is argued that this tendency is a universal attribute of human cognitive development directly caused by the combined effects of proactive inhibition and accelerated forgetting. We have shown that these effects are controllable as they are contingent on an individual's recognition of and conscious engagement with these fundamental psychological processes through the use of a mediational learning method. Mediational learning is possible due to the combination of three of our unique capacities, consciousness, language and reasoning. A new perspective has been developed regarding mediational leaning which permits the naturalization of phenomenon of consciousness. An outline of these recent developments in the CMP will be presented.

Learning Locally: TOSCG and Our Future

David Lloyd

University of South Australia

This presentation, "Learning Locally: The Old School Community Garden and Our Future" was motivated by experiences teaching gardening to primary students at a community garden. As an experienced educator I was motivated by the wholistic nature of this approach to teaching that contrasts markedly with subject oriented learning in school rooms which traditionally provide limited chances to see the world as a whole and to address local needs such as organic food growing (and eating). The garden provides learning opportunities which spread across many discipline areas and values the cognitive, the affective and the spiritual nature of learning in the natural world. This nature teaching crosses the many disciplines students' study and is part of the answer to liveable futures in this time of climate change and the crossing of other Earth boundaries.

Youth4Sea: Looking at the intra-actions within/around/between

*Marianne Logan, Amy Cutter-Mackenzie-Knowles, Lexi Lasczik, Antonia Canosa, Mahi Paquette
Southern Cross University*

This presentation investigates the intra-actions within/around/between the spaces of a youth framed participatory research project that sought to explore the understandings of young people (aged 18-24) in relation to Marine debris. Nine young people as co-researchers, developed and implemented an action marine debris plan targeting young people who visited Byron Bay (Cavanbah) during ‘Schoolies week’ 2017. Byron Bay is an Australian coastal surfing town in Arakwal Bumberlin country within the Bundjalung Nation.

A posthuman theoretical framing underpinned this arts-based ethnographic project. Visual ethnographic research methods include: photography, videos, visual diaries, interviews and collaborative painting. With diffractive analysis we look at the intra-action of data rather than looking at data in isolation. We pay attention to the past, present, and future entanglements and diffraction of time (Barad, 2010). Indigenous, post-colonial, alternative, surfing and scientific cultures and knowledge “thread through each other in a nonlinear enfolding of spacetime” (Barad, 2010, p. 244) within the Byron Bay location. The ‘intra-actions’ in contrast to ‘interactions’ mean “the events do not precede” one another but arise and this challenges the traditional conception of “causality” (Barad, 2007; 2010, p. 267). This paper provides vignettes of co-researchers’ stories woven within this ‘spacetime’ context.

Improving a science teacher’s epistemic teaching competence by implementation of ambitious science teaching practices

*Seungho Maeng
Seoul National University of Education, Republic of Korea*

This study showed an elementary teacher’s implementation of ambitious science teaching (Windschitl et al., 2018) practices and investigated her practices in terms of APT-epistemic performances (Barzilai & Chinn, 2018). The teaching context was to facilitate elementary students’ construction of constructing explanatory models of why the landscapes near upstream areas are different from those near downstream areas. Students’ (N=29) classroom discourses and their worksheets for seven science classes on weathering, erosion, and deposition were analysed to describe whether the learners’ epistemic performance was aptly conducted: whether it was successful, was based on their competences, and was conducted in appropriate ways for the learning goals. The results showed even elementary students could engage cognitively in epistemic performance when they constructed explanatory models for the difference of the landscape around a river. The practices adopted from the ambitious science teaching framework helped elementary students conduct epistemic performances by guiding how they talked and acted during the classes. However, their participation in epistemic performance was restricted to the argumentation on how they connected their explanations with experiments. The capacity of ambitious science teaching practices was discussed to improve elementary students’ epistemic performances and science teachers’ epistemic teaching competences.

Theoretical approaches to an SSI-STEAM teaching: Developing and evaluating an SSI-STEAM program

*Ha My (Anna) Mang, Hye-eun Chu, Sonya Martin, Chan-Jong Kim
Macquarie University*

The need to develop scientifically literate and active citizens has shifted attention to pedagogical approaches that integrate arts into STEM (Science, Technology, Engineering and Mathematics), or STEAM. However, questions have arisen about STEAM's capacity to meaningfully and authentically connect students to real-world problems. This gap could be addressed by integrating socioscientific issues (SSI) into STEAM instruction. However, there are limited discussions on theoretical frameworks and program evaluation tools that can guide teachers in planning and teaching an SSI-STEAM integrated curriculum. Using a design-based research (DBR) method, this study identified key principles that informed the development of an SSI-STEAM framework. This framework was translated into a program evaluation rubric for teaching and learning purposes, and then used to analyse the study's program and other existing programs. In this presentation, the science topic "Climate Crisis" was analysed.

The findings indicated that effective SSI-STEAM learning was dependent on four key principles: *Enacting values and practices*, *Affective learning*, *Authentic contexts and activities*, and *Interdisciplinary thinking and integrated practices*. These principles could only translate into program development by adding a sixth stage known as *Enact* to the 5E inquiry model. Many of the evaluated programs did not adequately meet the criteria for SSI-STEAM learning.

University teachers' design for preservice teacher learning in primary science education units in Australia: a pilot study

*Jenny Martin
Australian Catholic University*

This study investigates Australian university-based teacher educators' design practices for Initial Teacher Education (ITE) primary science education units using ethogenic social psychology. In Ethogenic Social Psychology, all human social action is understood as deliberate and motivated on two analytically distinct registers, the practical and the expressive, i.e. directed towards either instrumental or moral ends. Actions directed towards instrumental ends are necessary to produce the means of ongoing life. Actions directed towards moral ends maintain or disrupt normative relations between persons and social orders. Participating teacher educators' retrospective accounts of their design practice were sought as data. Online semi-structured individual interviews invited participants to describe and account for their unit design. Analysis focussed on the way in which the teacher educators discursively constructed the purpose of their design practice and particularly, whether their intentions could be described as practical or expressive. Preliminary analysis revealed that theories of science learning orient Australian teacher educators' practices in design for ITE primary science education units. The research adds insight into the well documented gap in the literature on how teacher educators transform their expertise in discipline-based education to teacher education and highlights specific concerns related to the development of primary science teacher educator practice.

Science teachers' perceptions of creative thinking as a general capability

Felicity McClure, Mihye Won, David Treagust
Curtin University, *Curtin University & Murdoch University*

Critical and creative thinking is one of seven general capabilities that the Australian Curriculum asks all teachers to foster to “enable students to live and work successfully in the 21st century”. However, while science teachers generally feel confident in developing critical thinking in students, they are less sure about what creative thinking in science looks like and how to encourage it. Thematic analysis of semi-structured interviews carried out with 13 science teachers in three Australian states revealed a wide variety of views about what creativity looks like in the science classroom. It revealed that some teachers hold restricted conceptions about what creative thinking in science entails, focusing on project-based or inquiry learning and communication of assignment responses in unique formats but not recognising the role of creative thinking in other classroom activities. They identified a number of barriers to both the teacher and the student in developing creative thinking skills, the most prominent of which were time limitations, pressure to cover curriculum content and assessment constraints. This study provides suggestions for supporting teachers in developing more diverse understandings of creative thinking and indicates some systemic concerns to address in order to support teachers and students in fostering creative thinking.

A macroscopic model introducing the particle nature of matter to upper primary school students

*Heather McMaster, Christine Preston, Hailan Wang
University of Sydney*

Properties of materials can be explained using a model showing matter to be composed of tiny particles. There is debate as to whether this model should be introduced in primary school. Students' measurement of solid objects in Mathematics can lead them to believe that volume is always conserved while in Science, they learn that heating a material changes its volume. This study aimed to determine whether introducing students to the particle nature of matter using a concrete macroscopic model, would help them accommodate a scientific understanding of why heat changes the volume of a material. Task-based interviews were conducted with six Year 6 students who observed that air in a balloon expanded when heated and contracted when cooled. Prior to this experiment, half of them were introduced to a simple macroscopic model of the particle theory of matter. Students' varied explanations and diagrams to explain the change in the size of the balloon, revealed that they held and continued to hold the belief that the volume of air is conserved when heated, because its mass is conserved. Only those introduced to the macroscopic model, believed that the number of air particles remained the same when the air was heated.

Teaching and leading practices of primary school teachers with a science specialism

*Reece Mills, Theresa Bourke
Queensland University of Technology*

Science teacher specialism in the primary school years is gaining advocacy internationally and within Australia, representing a significant shift in primary school education. Emerging scholarship has examined the varied teaching and leadership roles and responsibilities of these educators, however, there remains a paucity of critical scholarship problematising their work. In this small-scale qualitative study, we draw upon data generated from semi-structured interviews with six primary school teachers who identified as having a science specialism to answer the research questions: What are the teaching and leading practices of primary school teachers with a science specialism? and What factors enable and constrain the work of these educators? We used notions of practice architectures to thematically analyse the sayings, doings, and relating of primary school teachers with a science specialism. Our findings relate to tensions around models of specialism practices as well as whether teacher specialism ought to be located in the primary school years. We consider the implications of our study for science education scholarship, policy, and practice.

Teachers' perceived benefits of interacting with science centres

*Chloe Nelson, Supervisors: Jan van Driel, Victoria Millar
University of Melbourne*

Out-of-school science centres, including science museums, are common around the world and are visited by millions of school children and their teachers each year. Previous studies have highlighted a range of benefits for pre-service teachers interacting with science centres including knowledge gains and positive affective changes. However, less attention has been given to the benefits that in-service teachers experience through their interactions with these centres. This study presents the results of an investigation into in-service teachers' perceived benefits of their past interactions with science centres. A total of 55 in-service primary and secondary school science teachers from around Australia responded to a survey about their past interactions with science centres. The study confirmed that in-service science teachers experienced a range of professional growth benefits from their interaction with science centres including science content knowledge gains, increased motivation to teach science and subsequent improvements in their own students' learning. Teachers also described benefits such as connecting to other science teachers, science professionals and industry. Future research should explore the characteristics of science centres that contribute to these benefits and how these centres can contribute to fostering communities of practice.

Reflections on running an online conference during a global pandemic

Wendy Nielsen, Helen Georgiou, David Geelan, Angela Fitzgerald#
University of Wollongong, *Griffith University, #University of Southern Queensland*

An unanticipated impact of COVID-19 was the usual academic activity of in-person conference attendance. Many professional associations cancelled conferences in 2020 and 2021, but ASERA made a late decision to move to a wholly online conference format for 2020. This was a first for ASERA and its organizers. As our world adapts to ongoing life in

the pandemic that now may need to consider future pandemics in our work planning, the aim of this paper is to share reflections on a rapid shift from a F2F format to holding the conference entirely online during a period of lockdown and travel restrictions. Reflections from the conference convenors and a follow-up survey for ASERA's membership serve as data for this presentation. The convenors reflected on the initial decision to go online, the justification for the design of the online conference (including the decision to run it at no/little expense) and how it went, while the survey (n=91) sought perspectives from attendees on their experiences of this first-ever online conference for ASERA. Our aim is to contribute to greater understanding of running online research-related events, an occurrence that will become more frequent or likely as we adapt to the 'new norm' post-pandemic.

Science teachers' perceptions of what is important in STEM

Melanie O'Leary, Bruce White, Yvonne Zeegers**
*Catholic Education South Australia, *University of South Australia*

While STEM and STEM Education are not new, teachers' perceptions of what STEM means and how it unfolds as STEM Education is evolving and this impacts on how teachers implement STEM in the classroom (Wang, Moore, Roehrig, & Park, 2011, The Office of The Chief Scientist, 2017). It is therefore important when implementing STEM in schools to not only look at teaching approaches but also teachers' understanding of STEM and what they consider to be important for STEM Education. At the beginning of a STEM project conducted in Catholic Education South Australia schools, project teachers were asked, in a text response as part of a survey, to identify what they considered to be the most important aspects of STEM teaching and learning and to rank these from the most to least important. In the second and third year of the project the aspects identified in Year 1 were listed in the survey and teachers were asked to rank their top 5. Interviews with teachers were used to unpack these aspects and how their understanding of STEM was changing.

The top two aspects identified by the teachers were consistently Authentic/ real-world problems and Critical thinking. Teachers commented on their increased confidence to implement STEM and their greater understanding of the complexity of STEM as the project progressed. Additionally, as their confidence in their own pedagogical approaches developed, their view of STEM developed and the teachers who tended to have more holistic views of STEM tended to implement Inquiry Projects that centred on integrated/interdisciplinary approaches.

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Primary pre-service teachers with an expertise in science and mathematics: perceptions of indigenous knowledges and practices and incorporation into transdisciplinary units of work

*Kathy Paige, Lisa O’Keeffe
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Paige, Lloyd & Smith (2017, 2019) provide a set of eight eco-justice principles that underpin a transdisciplinary approach to science and mathematics teacher education for sustainability. The principles focus on imagining preferred futures, nature education, connections to place, active participation/activism and prioritising of *culturally responsive* pedagogies. With these principles in mind, we continue our on-going work with pre-service teachers (O’Keeffe, Paige & Osborne, 2019) exploring ways we can enhance their experience and challenge their perceptions particularly around eco-justice and equity in teaching mathematics and science. In particular, our current work with colleagues across the final year explores ways in which targeted interventions around culturally responsive approaches support pre-service teachers to include this approach in transdisciplinary units of work. In 2020, our research question, to challenge us as science and mathematics pre-service teacher educators, was ‘*How might a transdisciplinary, culturally responsive approach to education build knowledge and capabilities for sustainable futures with final year primary /middle pre-service teachers?*’ Pre and post data were collected, along with forum posts and samples of student work. In this presentation we focus on the pre-service teachers’ initial confidence ratings in integrating their understanding of Aboriginal and Torres Strait Islander histories and cultures, the topics of their transdisciplinary units of work and an analysis of their descriptions of units of work.

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Storytelling: Chemists, Crime, Fraud and Scandal

*William Palmer
Curtin University*

‘Story telling has recently been recognised as a powerful means for improving learning about science.’ (Gamito-Marques, 2020, p. 583).

Recently, I was researching the life stories of the authors of American Chemistry laboratory manuals. Almost all of authors to have led what appeared to be exemplary lives but one author whose manual I had admired for many years had committed a major fraud. This led me to the idea of attempting to connect chemists and crime by finding the stories of some villainous and scandalous chemists. Many stories connecting chemists with crime relate to forensic science

where the chemist's evidence in court leads to the conviction of a criminal. However, this study will provide examples of chemists or persons with an extensive chemical knowledge using that knowledge to commit a crime or committing a crime in the course of their chemical career. The examples chosen will provide instances to discuss the legal moral and chemical aspects of the cases. This could provide a useful starting point for courses involving a discussion of ethical issues in science.

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ScienceSing: Inspiring upper primary students to engage with science through song

Tracey-Ann Palmer
University of Technology, Sydney

Primary school teachers play a pivotal role in developing childrens' engagement with, and interest in, science. However, evidence suggests that many primary teachers are uncomfortable teaching science and need support. Songs can be effective in engaging students with science and a review of songs currently available was conducted. Most songs were not linked to the Australian curriculum and limited in the range of pedagogical practices they would support. There were many songs for lower primary but very few for upper primary. A new project, ScienceSing, aims to create song-based educational resources that are linked to the Australian Curriculum and specifically designed to engage upper primary students with science. Based on the results from a preliminary survey, eight curriculum-linked songs have been professionally produced. The songs are contemporary and, along with linked teaching resources, will be freely available for use under a Creative Commons licence. A study to determine the value of these songs as an engagement tool and the potentially to extend their use to support learning of scientific concepts and as a basis for student-centred and collaborative pedagogies is currently in progress.

Development and Application of IoT-based STEAM Program for Citizen Scientist Activity

Changmi Park, Hyun-Jung Cha, Seok-Hyun Ga, Chang Hyeon, Eom, Sung-Eun, Lim Ji-Hye, Kwon Seoha Na, Hyeijin Um, Supervisor: Chan-Jong Kim*
*Seoul National University, * Seoul National University Girls' Middle School*

In this study, the IoT technology-based STEAM program that students plan and execute as extreme citizen scientists was developed and applied to the middle school club activities and analyzed its effects. 17 students (age 14-15) participated in the activities, and after learning the basic concept of citizen science and atmospheric environment, they started citizen science activities. To analyze the effects of the program conducted in this study, the data were collected including activity data, STEAM core competency test sheet, online questionnaire, semi-structured interview, and researcher's research notes. As a result, students showed a significant increase in the 'convergence' element among STEAM core competencies. In addition, students' perceptions of science changed from that science was theoretically centered or that the results of the science experiment were the final achievement of scientific inquiry to that science was deeply connected to our lives and that voluntary scientific research could change their society. And students also showed improvement in their ability to

perform inquiry by discussing with team members how to modify inquiry problems or control variables themselves and thinking about the most effective way to visualize data. Finally, students participated more actively in the overall process of inquiry and improved confidence in scientific inquiry.

Why didn't they transfer? – factors affecting the transfer of science concepts by year 6 students

*Anne Pillman, Supervisor: Lindsay Conner
Flinders University*

Transfer of learning is core business for educators as it is both the goal of education and the means by which progress towards that goal is measured. This research investigates the factors affecting transfer of science concepts by year 6 students in South Australia.

Twelve classes (n=244 students) were divided into two groups and taught with either low challenge (tell and practice/bounded framing) pedagogy or high challenge (productive struggle/expansive framing) pedagogy using an AA/AB experimental design. Students' transfer of the targeted science concepts were followed through two units of work constructed to minimise variation other than pedagogy. High challenge pedagogy correlated with a small increase in the percentage of students transferring the target concept in the summative assessment task. However it appears that a range of other factors relating to the concept, the transfer task, student learning dispositions, the class and the teacher act together with pedagogy to impact on transfer. Implications of this for educators are discussed.

Teaching and Learning Climate Change Education: A Case Study of Upper Secondary Victorian School

*Veerendra Prasad, Helen Widdop Quinton, Supervisor: Efrat Eilam
Victoria University*

Climate change (CC) is currently the most systemic threat to life on Earth. In spite of the severity and urgency of the looming crisis, literature reveals that there is scarcity in studies addressing nations' CC curriculum implementation that is; taught and learnt in upper-secondary years. These years are particularly important, as they are the final formative school years prior to students' entry to adult life. By focusing on one school as a case study, this research examines teaching and learning of CC education in Years 11-12, within a Victorian upper-secondary school. Specifically, examining how is CC education conceptualised and implemented by the teachers and attained by the students. Semi-structured interviews were conducted with upper-secondary teachers and their students.

The results indicate that CC is addressed in silos by the various subject teachers. Teachers rely mainly on their prior knowledge when teaching CC, and have no formal support, leading to inconsistency in pedagogical content knowledge. Students expressed eagerness to learn more, however, they rely on media, as sources of information. Suggestions are made for strengthening the formal, implemented and attained CC education.

Being Systematic in Science: A taxonomic biography of the Shark Bay Pearl Shell

*Leonie Rennie
Curtin University*

Patterns, order and organisation is one of the six key ideas underpinning the Australian Curriculum: Science. Observing – using the senses to gather information about an object or event – is the fundamental science process skill. By Year 3, Australian students are expected to “order their observations by grouping and classifying”. In the biological sciences, the system used to order observations of living things is taxonomic classification. Biologists use a system of binomial nomenclature, created by Swedish naturalist Carolus Linnaeus in the 1750s, in which living things have a generic name and a specific name, based on their morphological features. Each living creature, thus described, will have its own unique name. But what happens when reputable sources disagree on that name? In this presentation, I document a taxonomic journey into the naming of one particular zoological species, the Shark Bay pearl shell, known until relatively recently by a diversity of biological names. This essentially scientific journey required delving into history and geography, as well as social, cultural, and political perspectives, to create a biography that explains how the Shark Bay pearl shell came to be known as *Pinctada albina* (Lamarck, 1819).

Local walks to engage young children in science

*Pauline Roberts
Edith Cowan University*

Science is everywhere in the lives of young children; however, it is often overlooked by teachers in daily interactions with children and materials. This research aimed to engage teachers from an early learning context in science opportunities based on walks within the local area. As part of a larger project, a professional development session was provided that modelled engaging young children with weekly walks in nature. This presentation provides a case study of one site where the staff initiated walks with children in the local surroundings including a wetland area close to the setting. Data was collected through observations of interactions between teachers and children and interviews with the teachers to determine what changes to discussions occurred during the repeated walks. It was identified that the children began to notice more detail about their local environment and to make connections between the sites they were visiting. The changes in the teacher knowledge, skills and perceptions meant that more conversations were had with the children about the plants and animals they encountered, and questions became more complex to guide the young children’s inquiries. The results indicate that examples of implementation and scaffolded support can assist teachers to engage more effectively with young children and science in local contexts.

Indigenous Automation in the Budj Bim eel traps and Brewarrina fish traps

*Nicholas Ruddell, Holly Randell-Moon
Charles Sturt University*

In secondary and tertiary school science settings, there are few Australian programs that integrate Indigenous and western knowledge systems in STEM. We contend it is timely that we move toward pedagogical frameworks that include both Indigenous and western

knowledge systems in the form of cross-cultural science. This paper discusses and realigns the way we view the theoretical space that exists between western and traditional Indigenous knowledge systems by focusing on Indigenous engineering principles of automation in the Budj Bim eel traps and Brewarrina fish traps. The eel traps at Budj Bim are a vast aquaculture network designed by Gunditjmarra peoples to manage and automate the flow of eels and fish. The Brewarrina fish traps, devised by the Nyemba peoples, are estimated to be one of the oldest human technologies and similarly to the eel traps, worked to automate fish farming. We use a case study approach to show how these can be used as a contemporary STEM learning resource, with suggested learning activities. Highlighting the case studies' use of automation is an impactful way of connecting Indigenous engineering to contemporary STEM debates about automation and engage students with Indigenous science as an ongoing and lived practice.

Engaging the Most Vulnerable: Challenges in Achieving Learning Outcomes during the COVID-19 Pandemic

Elvia Shauki, Destri Fitriani, Alfa Rahmiati**
**Universitas Indonesia*

This study aims to explore input variables, the learning environment variables, and learners' vulnerabilities that affect learning outcomes during the pandemic COVID-19. These outcomes include students' perceptions of proficiency in learning materials, technology, and communication skills. Input-Environment-Outcome (I-E-O) Model posited by Astin (1991) and Astin and Antonio (2012) were used. The pandemic's impact was measured by learners' vulnerabilities to environmental variables. A survey targeting undergraduate accounting students in 2 (two) public universities in Indonesia was developed to obtain the I-E-O components. The data were analysed using content, thematic and constant comparative analyses. This study finds that gender, perception of computer skills (first-time or non-first-time experience), and distance from the main campus (access location to online learning) are the identified input variables. Whereas learners' perceptions of the importance of engagement among peers and with their lecturers are the recognised learning environment variables. The vulnerability caused by physical and social/economic factors were added to the environmental variables that potentially reduced learning outcome. Physical and social/economic vulnerabilities due to the ongoing pandemic COVID-19 were included in the I-E-O framework. This study has practical and social implications. The social implication was acknowledged by putting into account the vulnerabilities experienced by the learners to improve the learning outcomes.

Keywords: Learners' Vulnerability, Input-Environment-Outcome (I-E-O) Model, Input Differences, Environmental Variables, Online Learning Delivery, COVID-19

Sustainability and Environmental literacy: Examining understanding, behaviour and attitudes of 1st year tertiary students

*Rachel Sheffield, Rekha Koul
Curtin University*

This research informs ongoing environment conversations around the 'Global crisis', 'Global and environmental emergency' and the ongoing 'war against nature' (Greta Thunburg, 2019). Marches across Australia and around the world have seen students leave school and be granted permission to leave University to participate in marches calling for changes and government reform. However here is little information about wider Australians' beliefs, attitudes, and knowledge of the environment. It was determined that individuals' knowledge, attitudes and beliefs would then provide a strong indication of their possible actions to make changes to protect the climate.

This project examined the environmental literacy of the 1st year University student community, that included student engineers and pre-service teacher, focusing on their knowledge, beliefs and behaviours using a pre-validated survey by Shih-Wu Liang, Wei-Ta Fang, Shin-Cheng Yeh, Shiang-Yao Liu, Huei-Min Tsai, Jui-Yu Chou & Ng, E (2018) that tested the environmental literacy of Taiwanese undergraduate students. More than 1000 1st year students completed the survey over several years and it was determined that all students demonstrated strong positive attitudes towards the environment, but many lacked key knowledge that would support their environmental literacy.

Exploring Students' Agency concerning Climate Change through Action-oriented School Club Activity

Hyeonjeong Shin, Suhyun Seo, Supervisor: Chan-Jeong Kim
Seoul National University, *Ihyeon High School*

Climate change is one of the most significant and urgent issues students should face deal with and respond act right now to respond to. A social action-oriented school club activity program for climate change was developed through collaborative action research with teachers. The study aims to explore students' agency to respond to climate change through their experiences of participating in school club activities. Four teachers and Forty-three secondary students in four schools in Seoul Metropolitan Area were participated for a year. The club activity programs had to be adjusted according to the pandemic policy for schools and school schedules changed frequently. This made substantial differences of program execution among schools. However, the cores of the program, the urgency of climate change and fostering their action competence, had been emphasized in all schools participated. Data were collected through interviews with, journals, photo essays, and social actions by students. Students' agency was explored and understood as expressed action that emerged from students' negotiation with structures such as the nature of climate change issue, the intention of teacher or program design, limited situation, etc. We discussed the implications for developing and applying for future action-oriented climate change education programs from the research findings.

**Students' willingness to act on their beliefs in reducing global warming as they age
(Grades 6-10): Comparative changes in culturally different countries**

Keith Skamp, Eddie Boyes, Martin Stanisstreet**

*Southern Cross University, *Formerly University of Liverpool*

Using a novel questionnaire, we explored - for the first time - whether a measure of students' (n > 12,000; Grades 6-10; 11 countries) willingness to act on their beliefs about the effectiveness of 16 actions in reducing global warming (GW) changed as they aged and whether these changes (in willingness to act on beliefs') varied in the different cultures of the 11 countries. Schwartz's quantitative measures of each country's position along three cultural dimensions (autonomy ↔ embeddedness, egalitarianism ↔ hierarchy, harmony ↔ mastery) were used. ANOVA analyses found students' willingness to act on their beliefs changed as they aged and such changes varied across different cultures: e.g., for some actions to reduce GW, students in more embedded cultures were more willing to act on beliefs compared to those in more autonomous cultures, and this willingness decreased (in both cultures) as they aged. Features of each cultural orientation could be aligned with the findings. Connections between students' willingness to act (on beliefs) and the actual effectiveness of measures to reduce GW and the perceived personal 'cost' (e.g., convenience, financial) of these measures were also explored across the cultures. A country's 'cultural press' on students' willingness to act to reduce GW has pedagogical implications for climate change education.

Understanding Problem Based Learning in school-based STEM education

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To explore Problem Based Learning (PBL) as a way to enhance Australian school-based STEM education, researchers from Monash University and Queensland University (UQ) are working with Melbourne Archdiocese of Catholic Schools (MACS) and Brisbane Catholic Education (BCE). This presentation reports on the findings from Phase One which addresses the question: What principles define the fundamental nature and intention of a PBL model of STEM Education? PBL experts in both science and engineering, from across Australia and internationally, were invited to take part in online focus groups. The analysis aimed to elicit some key principles, issues and values associated with PBL from a practice perspective. Findings identified a range of key considerations including, the typology of problems, the importance of context, teacher identity, the role of time, assessing a process of learning rather than focusing on the assessment of a product, and understanding the difference between problem solving and PBL. The significance of the learning environment, including access to and use of both physical space and learning tools was also highlighted. This information informs the next phase of the project which explores the development of a pedagogical framework for school-based STEM education.

Primary School Girls' STEM Education Experiences – A Pilot Study
Tabetha Spiteri, Supervisors: Amanda Berry, Rebecca Cooper, Jared Carpendale
Monash University

There have been calls for more research into STEM education in Australia, particularly, the impact of STEM education on girls' STEM attitudes and aspirations (Department of Industry, Science, Energy & Resources, 2020). This presentation will discuss the results of a pilot study conducted as part of a larger PhD study into girls' integrated STEM education experiences during the transition from primary to secondary school, and how girls' STEM attitudes and aspirations are influenced by these experiences. A qualitative methodology was used to capture girls' STEM classroom experiences from their perspective. Participants for the pilot were a small number of 11-13-year-old girls from one Melbourne K/P-12 school with a dedicated STEM program. These girls were invited to photograph their STEM classroom experiences at the beginning of the school year, and to select two of their photographs to use as visual aids when discussing their experiences in a follow-up focus group interview. Results from the pilot will be used to test and refine the methodology to be undertaken in the main study, and will provide sought-after evidence into the impact of STEM education on girls' STEM attitudes and aspirations in an Australian context (Department of Industry, Science, Energy & Resources, 2020).

Meeting the challenges of accessibility for science inclusive classrooms: Indonesia's portrait

Jamil Suprihatiningrum, Supervisors: Carol Aldous, Carolyn Palmer*
** Flinders University & State Islamic University, Indonesia, Flinders University*

There is no one-size-fits-all answer to supporting a student's learning needs. However, accessibility for every student to achieve the same learning goals is critical to an inclusive environment. Seven participants from three Schools Providing Inclusive Education (SPIE): viz Cerdas, Pintar, and Pandai in Yogyakarta Indonesia were selected purposively and interviewed to share thoughts and experiences about meeting the challenge of learning accessibility for students with disabilities (SWD) in science. Each participant was invited to consider how learning was achieved and what means were provided to help students learn. Data were analysed systematically, and three themes emerged viz: inclusive pedagogy, inclusive content and inclusive technology. Findings indicated that although a science syllabus was made available, expectations for SWD were set low and learning objectives ill-defined. Although time to co-plan was limited, a collaborative teaching approach existed in Pandai where teachers were found co-creating different worksheets to meet a given student's need. Teachers in Cerdas and Pintar indicated that they had no time to either vary or accommodate for different modalities in learning science. Although all teachers understood how SWD need interaction with different tools, only teachers at Pintar and Pandai were utilising assistive technologies to help SWD in learning science.

Keywords: accessibility, inclusive classroom, inclusive pedagogy, inclusive content, assistive technology

Exploring how the Figured Worlds of five Auckland Primary/Intermediate schools affects the performance of science.

Carrie Swanson

Auckland University of Technology, New Zealand

The New Zealand [NZ] curriculum is a framework curriculum and therefore there is wide variation in science teaching. The research aim was to discover how science was taught at primary/intermediate schools in Auckland, NZ and the reasons for the pedagogical approaches chosen. International and national studies have highlighted student science understanding has been declining for over twenty years. This study may inform future directions to improve students' understanding of science. Using an interpretive, qualitative approach, semi-structured interviews were used to ascertain senior management's views on science teaching and learning from five schools. Themes were collated under Holland et al.'s (1998) key ideas of figured worlds, actors, actions and outcomes. The figured worlds ranged from innovative learning environments to single cell classrooms, with pedagogical approaches on a spectrum from integrated units to stand-alone experiments. It was apparent science learning was impacted by the figured worlds of the school and actions and outcomes deemed important by senior management. However, the performance of science was dependent upon the actor's (teacher's) self-efficacy, time allocated, resources available and positioning of science. This paper will comment on the similarities and differences between the figured worlds and the affordances and constraints offered to science teaching and learning.

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Time to Challenge the Limitations of What Science Concepts are Taught in Primary School

*David Treagust, David Blair**

*Curtin University, *University of Western Australia*

The most consequential development in educational practice over the past 50 years is the change of focus from classrooms being teacher-centred to being student-centred. Much of this change has been supported by the work of Piaget with the stages of concrete and formal operational thinking giving rise to hands-on science curriculum in primary and lower secondary school. These levels of thinking also bring restrictions that abstract concepts should not be taught in primary school. For example, the Australian National Curriculum stipulates that the concept of atoms should only be introduced in middle school. In primary school heat is taught without mention of atoms and light is taught without mention of photons. So how are primary students expected to develop an understanding so that they can explain the phenomena to which they are engaged? Empirical evidence from research in educational psychology shows that there is considerable plasticity in young children's capacity to understand abstract scientific ideas, especially when presented appropriately with hands-on activities and an enquiring learning environment. Our research introducing Einsteinian physics concepts to primary and lower secondary students shows that these students appreciate the atomic description of matter (atoms, electrons, photons) because it has such strong explanatory power.

Student-generated Diagrams to Engage Students in Understanding Science Concepts

*Sherab Tenzin, Supervisors: Mihye Won, David Treagust
Curtin University*

Student-generated science diagrams have the potential to help students explore causal explanations for many science phenomena. We investigated how this activity helped students learn fundamental science concepts and understand causal explanations. Sixty-one Year 7 students from a high school in Australia participated in the study. A total of 183 diagrams from three physics lessons were analyzed for the study. The analysis of the diagrams showed evidence of students' engagement with the content and efforts to understand the causes. Many students used appropriate representational conventions such as arrows with varying length, thickness, and numbers to represent forces with different magnitude. They also showed the overarching concepts of balanced and unbalanced forces in their diagrams more consistently as the lessons progressed. Some students successfully provided causal explanations, but the majority struggled to construct causal explanations. Nevertheless, drawing diagrams helped students see the links between observations and key science concepts and between the concepts. Student-generated diagrams also provided teachers with an overview of students' conceptual understanding and difficulties, which could be used to tailor their support for students. The analysis showed that student-generated diagrams can assist students' knowledge construction, provide information for teachers to scaffold students' learning and plan future lessons.

Transduction as fundamental to learning science

*Russell Tytler, Vaughan Prain
Deakin University*

There has been increasing recognition of the multimodal nature of knowledge development (Gooding, 2004; Latour, 1990) and learning (Lemke, 1990). While much research has focused on identifying the affordances of different modes and the ways in which different representations are enlisted to describe and explain phenomena, the question of how the meanings entailed in concepts shift and expand across modes (Lemke, 1990), titled 'transduction' (Kress, 2000), has been less explored. Yet the transduction process is fundamental to students realising, aligning, generating and coordinating representations in learning science (Kozma & Russell, 2005; Volkwyn, 2019). In this presentation we will draw on a range of primary school activities and sequences designed around representational work to explore the fundamental role of transduction in student reasoning and learning and the challenges this entails. In the Interdisciplinary Mathematics and Science (IMS) project we have developed a pedagogy with stages of orienting, posing representational challenges, evaluating and building consensus, and applying and extending conceptual understanding. We will analyse student artefacts to explore the fundamental role, the nature of, and challenges associated with transduction as students engage with material and representational work. We will describe the strategies teachers use to support this fundamental process.

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Cognitive Load Theory and the human movement effect

*Kylie Walters, Brendan Bentley
University of Adelaide*

Despite the Australian government's national focus on improving student learning outcomes in science-based subjects, a continual decline remains. The intrinsically complex and abstract nature of science-based concepts has proven difficult for secondary students to master. Recent advances in cognitive research have provided educators with practices to improve learning and mastery. The drawing together of the principles of Cognitive Load Theory and Geary's evolutionary educational psychology centred on specific human gesture has provided educators with the opportunity to design learning tasks sympathetic to reducing working memory load. The study investigated the effect of a specifically designed learning task using hand gestures in a Year 8 secondary school science class on the topic of particle theory/Brownian motion. The study found students who received specifically tailored content-congruent gestures had a beneficial effect on achievement and cognitive load scores when compared to students who experienced the same scientific content taught by traditional teaching methods.

Executive functions and the suppression of naïve thinking in science education: a cognitive psychology task exploring the relationship between inhibition ability, cognitive flexibility and science learning

Rui Wang[#], Aaron Britton^{}, Harriett Godfrey^{*}, Supervisors: Aidan Feeney^{*}, Michelle Ellefson[#]*

[#]University of Cambridge, ^{}Queen's University Belfast*

How to correct students' misunderstanding of counterintuitive science theories such as 'the Earth is flat because the ground seems flat' has long been discussed. Previous studies found that naïve thinking is not replaced by scientific thinking but is suppressed when counter-intuitive conflicts are encountered; furthermore, the inhibition ability (an important executive

function) is involved in this suppression process. To explore this further from a cognitive perspective, this research tests 151 adults using four computerised cognitive tasks that test interference and behaviour inhibition abilities, cognitive flexibility (another executive function) and counterintuitive science reasoning respectively. Results indicate that cognitive flexibility is positively related to the ability to suppress naïve thinking and has different links to two forms of inhibition, indicating that the suppression of naïve thinking and the activation of scientific thinking occurs simultaneously when solving counterintuitive science questions. This result suggests that when teaching counterintuitive science theories, 1) providing students more time to solve those counterintuitive questions that require complex cognitive processes and 2) emphasising and better explaining correct science theories during teaching to shorten the time to activate new information (as opposed to merely emphasising that naïve ideas are wrong) might improve students' learning outcomes.

Teaching Science through STEM inquiry projects

*Bruce White, Lisa O'Keeffe, Melanie O'Leary**

University of South Australia, Catholic Education South Australia

One approach to implementing STEM in schools, is through the use of inquiry projects (The Office of The Chief Scientist, 2017). However, a move towards learning science through STEM inquiry may require changes in teachers' practices (Timms et al., 2018). What is not always clear is what teaching practices best support student learning in inquiry projects/inquiry based pedagogical approaches (Murphy et al., 2019). This presentation draws from data collected as part of a STEM project conducted in partnership with Catholic Education South Australia schools. This STEM project supported teachers in development and enactment of STEM Inquiry Projects. Teacher and student perceptions of the teaching approaches most frequently used during the inquiry projects and teachers' self-reported confidence to teach science in an interdisciplinary environment will be presented and discussed.

Teachers reported significant increases in their knowledge of inquiry approaches and how to teach science in an interdisciplinary environment. Inquiry projects that required authenticity, critical thinking, and a need to communicate and collaborate created more opportunities for student centred approaches to teaching and learning, and this in turn impacted positively on pedagogical practices in Science.

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Linking mathematics and science productively

Peta White, Russell Tytler, Joanne Mulligan, Melinda Kirk**
*Deakin University, *Macquarie University*

The Interdisciplinary Mathematics and Science (IMS) project has developed, trialled and refined learning sequences across years 1-6 that productively link mathematics with science in ways that enhance fundamental learning in each subject. The principles of this interdisciplinary linking include: there is fresh learning of foundational constructs in both subjects; each subject enhances learning in the other; and attention is given to progression of knowledge and skills. A central feature of the sequence design is attention to authentic disciplinary epistemic practices through students inventing, evaluating and refining representations. We will draw on a Grade 2 sequence in paper helicopter flight that involves mathematical constructs of measure, variation, and data modeling, to a). illustrate the interdisciplinary design principles and how they operate to enhance learning, and b). explore the challenges for teachers in implementing such interdisciplinary learning. These challenges relate to: teacher pedagogy, epistemology, and knowledge; the need to flexibly interpret and anticipate curriculum progression; and the lack of support in traditional mathematics curriculum practice for this epistemic vision. We will explore the variation in ways in which the mathematics and science interrelate in the different sequences.

Metacognitive outcomes of research skill development across a science degree

John Willison
University of Adelaide

This paper presents a study on explicit Research Skill Development (RSD) and assessment in courses in the first two years of a Bachelor of Animal Science. In the fourth, research-focussed year (Honours) the metacognitive outcomes of RSD were investigated. This focus was taken because metacognition has been shown to be one of the most powerful factors affecting student learning that may be influenced by teachers.

Research question: What is the evidence for different levels of metacognitive thinking when fourth-year Bachelor of Animal Science students are interviewed about their development and use of research skills in multiple contexts across their degree?

The interpretivist methodology used semi-structured Interviews with students that were conducted 18 months after explicit research skill development. Interviews focused on probing for rich examples of students' research thinking during their course-based experiences, however no questions cued metacognition explicitly. A 5-level metacognition framework was synthesised from the literature, comprising Core metacognition, self-Awareness, self-Monitoring, self-Regulating and cognitive Transfer (CAMRT) and used to analyse the interview transcripts.

Embedding principles of Indigenised learning into tertiary primary science education curriculum

Kimberley Wilson, Phillip Dreise

Traditionally, science education has been an area where there has been minimal inclusion of Indigenous perspectives as a result of a number of factors including the dominance of Western science narratives, the marginalisation of diverse groups within the discourse of science, and a prevalent view of Indigenous or Traditional Ecological Knowledge as being less rigorous than Western Science (Aikenhead, 2006). Recent Australian Curriculum initiatives, including the development of 95 content elaborations targeted at embedding Indigenous perspectives in Science, reinforce the imperative for all educators to develop the self-efficacy and capability to embed diverse perspectives in science lessons in a way that moves beyond tokenistic attempts at inclusion. The intent of this project has been to establish the preparedness of academic staff to support pre-service teachers to integrate Indigenous knowings in science education, and to investigate areas of challenge and possibility. The method for this project has been embedded in an action learning model with an overall goal of establishing a professional learning community dedicated to improving pedagogical practice. Findings of the project indicate that goodwill on the part of staff could act as a platform for transformative practice that embraces and reflects a full realisation of the complexity of Indigenous knowings.

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Interdisciplinary learning in mathematics and chemistry: A case study of two primary classrooms

Lihua Xu, Chris Speldewinde
Deakin University

The advocacy of interdisciplinary approaches to teaching and learning in the STEM subjects presents a strong critique of traditional science and mathematics curricular in their capacity to support student development of 21st century skills and dispositions required for the future (Tytler, et al., 2019). Empirical studies that demonstrate the benefits of the advocated interdisciplinary approaches are still emerging. This presentation reports on an empirical study of two primary classrooms where an interdisciplinary approach to science and mathematics has been developed and enacted as an intervention. This study employed a design-based research methodology (Cobb, et al., 2003), focusing on student representation construction and model-based reasoning through a guided inquiry pedagogy. Both teachers enacted an interdisciplinary sequence, designed by the research team, focusing on concepts in chemistry (physical change) and mathematics (data modelling) with grade 5 students. Drawing on classroom data, student work, and interviews, we demonstrate 1) the different directions that each teacher undertook in guiding student exploration of physical change through data modelling, and 2) their connections to the variations evident in student representations. The findings have implications for designs of future interventions that promote interdisciplinary learning and the support needed for effectively enacting such interventions in primary classrooms.

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Learning Nature of Science through Inquiry-based Reading

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The importance of Nature of Science (NOS) is shown in the revised curriculum benchmarks or standards in many countries. To develop students' understanding of NOS, popular science texts offer good discussion materials for history and philosophy of science (HPS) and socio-scientific issues. Inquiry activities that enable students to understand how scientists study the world is a good teaching strategy for NOS instruction. This study attempts to investigate how one literacy teacher and two science teachers through co-teaching a 16-session unit (approximately 720 mins) develop students' understanding of NOS through inquiry-based teaching and self-designed experiments. Selected readings included a chapter which discussed how Darwin and Wallace collaborated and competed when developing the theory, articles about scientists' endeavors and social values toward the pandemics and etc. The results from the pre- and post-tests of VNOS questionnaires indicated a significant improvement in students' understanding of inference and theoretical entities as well as social and culture influences. A variety of techniques that the literacy teacher and science teachers used in inquiry-based reading activities and weight-measuring experiments were identified, analyzed, and discussed.

Factors Affecting the Assessment Quality of Students' Scientific Argumentation Competency

Jinglu Zhang

University of Bristol

Argumentation plays a central role in science education because it leads students toward deep learning by engaging them in the practice of constructing and evaluating scientific arguments. There has, however, been little study on developing assessment instrument for this practice despite the growing interest in the topic. This paper explores the factors that should be considered to improve scientific argumentation competency (SAC) assessment based on a three round qualitative study in an iterative process of developing a SAC assessment instrument. By analysing data from interviews of teachers, cognitive think-aloud interviews of students, and after-test follow-up interviews of students in each round of the study, the

instrument was modified and prepared for the next round of the study. The author analysed all the interview transcripts using thematic analysis. The study found that overlapped factors emerged from teachers' and students' interview, and no new factors contributing to the instrument improvement appeared in the third round of the study. There are in total 10 factors to be considered as important in promoting SAC assessment instrument design. The author argues that these factors provide detailed information in supporting SAC assessment research although its universality has not been tested.

Poster Abstracts:

Complex Immunological Concepts Can Be Effectively Taught Via Interactive Simulations

*Maurizio Costabile
University of South Australia*

Immunology is known to be a challenging subject for students. Some reasons for this include complex content-specific terminology, numerous cellular and protein interactions during an immune response and reactions occurring at an invisible molecular level. To facilitate student learning, the author has developed a range of interactive simulations to aid in learning complex immunological concepts in an undergraduate immunology course. The simulations were prepared using Articulate Storyline, converted into a SCORM package, and loaded onto the Moodle learning management system. 2nd-year students had free access to all simulations throughout the semester, which were used in conjunction with traditional lectures. The impact of each simulation was assessed through a quiz, an end of semester examination and a questionnaire. Each simulation was highly interactive and could be completed within 15 minutes. Since their introduction, there has been a significant improvement in student performance in all instances, ranging between 20-30% in assessable components. Once developed, each simulation can be used for many years and adapted for new content within the course and related courses. Student feedback is consistently highly positive, and this approach continues to be expanded. If you are interested in using this approach, please feel free to contact the author.

An Investigation of Children's, their Parents' and their Teachers' Perceptions of Engineers and Engineering

*Miranda Ge, Supervisors: Jonathan Li, Amanda Berry, Julia Lamborn
Monash University*

This presentation explores children's, their parents' and their teachers' perceptions of engineers and engineering, through a literature review, proposed research, results of a pilot study and future implications. Historic and recent trends indicate that there is a decline in Australian students pursuing engineering careers, with this field also suffering from a lack of gender and ethnic diversity. An explanation, limited in the current landscape of work which has been conducted within this area, revolves around perceptions towards engineers and engineering. Perceptions are "extremely powerful and influential in human thought and behaviour" (Given, 2008). Perceptions towards particular subjects and careers are established early in the home and during primary school, guiding selection of academic coursework throughout schooling, ultimately impacting career opportunities (Lyons & Thompson, 2006). Underpinned by the Social Cognitive Theory (SCT) as a theoretical framework, this research will follow a sequential explanatory mixed methods approach, where a large-scale, cross-sectional study will be implemented, in which data will be collected via two methods: self-completion questionnaire and semi-structured interview. By crystallising what engineers do, what engineering is and transforming stereotypes, we may stimulate more exploration into STEM subjects and ultimately, a career in engineering.

Assessing undergraduate students' systems thinking competency using a scenario-based tool

Shu-Chiu Liu

National Sun Yat-sen University, Taiwan

Colleges and universities play a central role in developing future citizens and leaders capable of tackling the systemic issues behind complex problems such as climate change. There are however few attempts to assess systems-related competencies beyond survey instruments aimed at self-reported attitudes and behaviours. In this study, we developed a scenario-based assessment tool based on Grohs, Kirk, Soledad, and Knight's work (2018) to measure undergraduate students' systems thinking competency in complex problem-solving. This tool included (1) a locally relevant, but fictitious, climate-related problem scenario, (2) eight follow-up prompts, and (3) a scoring rubric for student responses to these prompts. Using this tool and an additional knowledge survey, we investigated undergraduate students' systems thinking competency and its relationship to content knowledge. We further examine whether and how a semester-long introductory course addressing climate change impacted students' systems thinking and their content knowledge about climate change. Among the enrolled students invited to participate in pre- and post-tests, a total of 110 agreed and completed the pre-test. Due to special pandemic circumstances, only 48 students completed the post-test. In the presentation, we will discuss the development and application of the scenario-based assessment tool and the preliminary results from the pre- and post-test data.

Online Design Thinking Professional Development for School Teachers

Siamak Mirzaei, Mandi Dimtriadis, Supervisors: Trent Lewis, Mirella Wyras
Flinders University, *Makers Empire Industry Partner*

Teaching and developing design thinking skills is challenging and technology use supports learners in overcoming such challenges. Makers Empire as an Adelaide-based 3D technology company provides a multi-platform, user-friendly 3D design software solution to primary schools to help both students and teachers with their design thinking skills and curriculum design tasks, respectively. While students interact with software environment, teachers are supported by online and in-person (Learn by Design) professional development (PD) courses to develop effective pedagogies for maker-based learning. Makers Empire has recently started evaluating and revising the online and in-person PD courses via conducting usability/learnability testing (via surveys) and aims to improve the users' learning/interaction experience. This presentation will focus on findings pertaining to a) efficacy of the current PD learning modules in supporting teachers to use Makers Empire's products and their integration into teaching and learning practice using maker-based pedagogies, b) feasibility of offering Learning by Design face to face PD course using remote and online delivery methods, and c) pedagogical and usability recommendations on improving current/developed PD courses.

Examination of a role-play-based school science lesson on electric current including programming activities

*Hayashi Nakayama, Tomokazu Yamamoto
University of Miyazaki, Hyogo University of Teacher Education*

As per Japan's new curriculum, the sixth-grade unit on 'use of electricity' should include programming activities, such as developing iPad programs that automatically switch lights on/off using a sensor. This curriculum revision requires a new teaching model for Japanese educators. Therefore, we developed a teaching model wherein schoolchildren can learn the scientific concept of electric current through programming activities. Our teaching model is based on six design principles and the following key point: 'schoolchildren explain desired device behaviour and programs to others using scientific terms and concepts'. Currently, we improved the lesson by introducing scaffolding by prompting. This was tested in a science classroom role-play situation, wherein 11 undergraduate students planned and conducted a primary school science lesson as the teacher group and another group of 21 undergraduates participated in the exercise as schoolchildren. During the lesson, the 'schoolchildren' filled out worksheets scaffolded by the prompts that were displayed on a screen. They mentioned electric current or electric circuit while providing explanations on the worksheet. We thus conclude that this lesson improvement based on the design principle effectively helps schoolchildren learn about electricity through programming activities.

Exploring the teaching strategies and effect of a STEM project-based module for young indigenous children in Taiwan

*Min-Erh Wei, Supervisor: Ching-Ting Hsin
Department of Early Childhood Education, National Tsing Hua University, Taiwan*

Quality early STEM curricula are crucial to help young children in Taiwan to develop science practices. However, little research has focused on kindergarten teachers' teaching strategies and their effects on children's science practices. Also, Indigenous students tended to have low science achievement. Therefore, the purpose of this study was twofold: to identify the teaching strategies used in the project-based STEM module and to examine the effects of the teaching on children's science practices. Using a multiple case study method, we recruited 2 teachers and 30 kindergarteners (average age: 5.6 years old) from two classrooms. Classroom observation data were collected. A performance-based assessment regarding science practices was applied before and after the module. Qualitative data analysis techniques were used to identify the teaching strategies and seven were found to promote children's science practices: demonstrating, comparing and contrasting, using multiple representations, probing, reviewing, giving direct guidance and providing emotional support. A Wilcoxon signed-rank test was applied to examine the children's development of science practices. Children in both kindergartens had significantly better performances after taking the module. This study sheds light on effective teaching strategies that help to foster young children's science practices.

Symposium Abstracts

Symposium Title: Contemporary Inquiry on Emotion and Affect in Science Education: Expanding the Research Programme

*Organiser: Alberto Bellocchi
Queensland University of Technology*

Science education research on emotions and affect has expanded in recent years. Despite this recent development, this programme of research remains underrepresented in mainstream publications, and staffed by fewer researchers when compared to some of science education's long-running research foci. This symposium showcases cutting edge work in science education from the Studies of Emotion and Affect in Education Laboratory, a group of science education researchers conducting international inquiries into a range of science education contexts. Presentations address topics including the role of emotions, social bonds, and values in science education contexts including science inquiry, nature of science, entrepreneurial science inquiry, and student engagement in Chemistry. Empirical outcomes from studies in Australia and Brazil inform novel understandings about diverse science teaching and learning experiences. Considerations for expanding the international sub-field of science education research on emotions and affect are provided as each study offers directions for further research. Overall, the symposium represents a showcase and invitation to join a thriving international research programme from an Australian led initiative.

Paper 1: Understanding student emotion to enhance science inquiry practices.

*Subhashni, Appanna, Supervisors: Alberto Bellocchi, James Davis
Queensland University of Technology*

Current science inquiry teaching practices are limited in their capacity to support student engagement and to develop literacy as they are not informed by research on students' emotions; rather, the professional development provided to assist teachers in science inquiry has chiefly focused upon enhancing teacher knowledge on the subject matter and modelling the enactment of inquiry. Such procedures limit the opportunities to develop teaching practices that are inclusive of students' emotional needs. This study uses a combination of interpretive and participatory paradigms to explore students' emotional experiences during science inquiry in a Year 10 Chemistry class to inform and support science inquiry teaching practices. Drawing on sociological theory of emotions, and using thematic analysis of student reflections and accounts from discussions between students, teacher, and the researcher, an approach is identified that supports science teachers to build an awareness of students' emotions and how these influence learning during science inquiry. Findings offer implications for classrooms in identifying ways of addressing emotional barriers to science inquiry learning and extending emotion research in science education by developing a model of emotional inquiry practice through reflective discussions to inform science inquiry teaching practices.

Paper 2: "Chemistry is not a subject that everybody understands": Sustaining engagement with Chemistry lessons and strengthening classroom social bonds.

*Priscila Rebollo de Campos, Supervisors: Alberto Bellocchi, James Davis
Queensland University of Technology*

Student disengagement with school science is a global concern. While students' perception of science as difficult is described as decreasing student engagement with school science, classroom social bonds, or persons' social and emotional connections, are reported as promoting it. Drawing on a micro-sociological theory of social bonds and interpretive methodology, I aim to investigate the interplay between 11th grade students' perceptions of Chemistry and their teacher's practices, classroom social bonds, and student engagement with lessons. Data are generated remotely from a Brazilian context through reflective diaries, interviews, video recordings of online lessons, and field notes. Although some students perceive Chemistry as difficult, they report that the teacher's instructional practices contribute to building a safe and relaxed environment. In such an environment, social bonds between peers and between a student (i.e., Alice), who got a wrong answer to a question in a lesson, and the teacher are strengthened. As a consequence, Alice's engagement with lessons was sustained. Findings have implications for future research on social bonds in science classrooms as a means of addressing the issue of student disengagement with school science. Future studies of social bonds may be conducted either in online or face-to-face science classes in multiple countries.

Paper 3: Exploring emotional engagement during explicit nature of science instruction in an Australian pre-service science class.

*Tshewang Namgyel, Supervisors: Alberto Bellocchi, James Davis
Queensland University of Technology*

Nature of Science (NOS) is a concept developed by science education researchers to study scientific epistemologies. Studies on NOS have been predominantly focused on cognitive engagement and do not include emotional engagement during NOS instruction. However, there is evidence of relationships between emotion and reasoning in scientific practices and numerous studies have established connections between students' emotions and science learning. This study explores the interplay between pre-service science teachers' emotional engagement during explicit NOS instruction. A multi-method approach was used to collect qualitative and quantitative data, including an open-ended emotion diary, video recordings of classroom interactions, and the Student Understanding of Science and Scientific Inquiry (SUSI) questionnaire. Data from the descriptive analysis of the SUSI questionnaire and the thematic analysis of emotion diaries were used to identify salient emotional experiences that focus on seven aspects of NOS during classroom interactions in video recordings. Video data were interpreted through the Intensity Model of Emotional Energy model to describe participants' emotional experiences during NOS instruction. Findings of this study may have a novel contribution to knowledge by discovering the interplay between participants' emotional engagement and aspects of NOS enacted during tricky tracks activity.

Paper 4: Creating values in science education through entrepreneurially infused inquiry.

*James Davis
Queensland University of Technology*

Values are experienced as cognitions infused with emotion, and how they take shape in science education is under-researched, which is problematic given the importance of epistemic values to the nature of science. The present study explores the creation of value and values by building on links with entrepreneurial education that are previously explored, but not fully developed, in science education research. Using an entrepreneurial Value Creation

Pedagogy (VCP) model as a conceptual framing, this study is situated in a science inquiry project as part of a preservice teachers' course. The study focuses on the question: *How are values in science education created by learning through doing an entrepreneurially infused inquiry project?* Using thematic analysis of student reflections, it illustrates how values are created for self to produce a sense of purpose, for agency to support actions in a science investigation, and for others. The study illustrates connectivity between creating values and learning practices in science education. Findings propose the utility of an entrepreneurial model of value creation as a conceptual framework for further investigations into the interplay between social, cultural and epistemic values in naturalistic science learning contexts. This may involve analysing emotive experiences as constituents of epistemic values.

Symposium title: Pro-active Teaching for Eco-Just Re-worldings: Reinforcing Application-based Learning

*Organiser: Larry Bencze
University of Toronto*

Humanity is facing myriad 'wicked' problems - including those linked to petroleum combustion, surveillance systems, manufactured foods, etc. - associated with capitalism-influenced science and technology. Assuming capitalist manipulation of public knowledge and subjectivities and learners' diversities in terms of abilities, cultural and social capital, etc., the four papers in this symposium provide theoretical and empirically-based arguments for proactive education of students, accompanied by personally-relevant application activities, about possibly-problematic relationships (eg drawn from Science & Technology Studies) among science and technology and societies and environments and encouraging and enabling them to develop/implement sociopolitical actions to overcome harms of their concern.

Paper 1: Material and Affective Power in Technoscience Relationships: Insights from STS

Sarah El Halwany, Majd Zouda, Minja Milanovic, Nurul Hassan, Jasmine Yeung,
Supervisor: Larry Bencze
University of Toronto, *Bishop Strachan School*

McGinn and Roth (1999) had argued that fields of Science and Technology Studies (STS) offer science education important educational aims that reflect "situated, contingent, and contextual nature of science, while also acknowledging the diverse range of communities and locations where science is created and used" (p. 17). Fields of STS can offer science education equally important opportunities to discuss '(bio)political economies of technoscience' (Birch, 2013) — a growing area of study within STS that remains underexplored within science education (research). Of interest are "ways science (or knowledge of the natural world) is embedded, embodied, and enacted in particular political conditions" (Freitas et al., 2017, p. 553). We reviewed academic articles in these STS journals: *Social Studies of Science*, *Science as Culture* and *Science, Technology and Human Values* (2010-2020). We conducted thematic analyses (Patton, 2002), focusing on (bio)political economies of science and technology. Notions from STS highlighted in this paper include: 'emotive actants', 'anthropocentric temporalities', 'sociotechnical imaginaries'

and ‘regulatory capture’. We discuss how such notions from STS could have implications for how we teach students about problematic technoscience relations, while accounting for often-overlooked discussions of power as material and affective.

Paper 2: Negotiating Merits of Inquiry-based Learning: A Self-study

Jasmine Yeung, Sarah El Halwany, Nurul Hassan, Minja Milanovic, Majd Zouda,
Supervisor: Larry Bencze
University of Toronto, *Bishop Strachan School*

Inquiry-based learning (IBL) is currently one of the most popular approaches to teaching science (Pedaste et al., 2015). This paper reports changes in my professional practice as a K-8 teacher, specifically my views and practices of IBL after being exposed to the ReAction Pedagogical framework. ReAction sees IBL to be problematic when students are expected to discover often difficult concepts on their own (Author6 & Collaborator1, 2011). Using a self-study approach (Hamilton, 1998), artefacts from my teacher education and teaching practice were analyzed, using constant comparative methods (Charmaz, 2014), to compare my pre- and post-ReAction teaching practices. Using the Learning Control Model by Lock (1990), themes in my teaching philosophy were mapped to illustrate extents to which my practices as a teacher changed on the spectrums of teacher vs student-directed and open vs closed-ended. Findings suggest that post-ReAction, I believe more teacher-directed approaches to start, with conclusions moving from closed-ended to open-ended as students gain attitudes, skills and knowledge to engage with science, are needed to attain the analyzed themes (engagement, student understanding and critical thinking). With the widespread implementation of IBL, this self-study raises further questions to deeply consider uses of IBL in relation to equitable teaching practices.

Paper 3: Reimagining Possible Futures: Negotiating Sociotechnical Imaginaries in a Science Classroom

Majd Zouda, Sarah El Halwany, Nurul Hassan, Minja Milanovic, Jasmine Yeung,
Supervisor: Larry Bencze
University of Toronto, *Bishop Strachan School*

Technoscience developments are continuously forging new (un)expected/(un)intentional possibilities, with beneficial and problematic consequences. Controlling all possible consequences of emerging technoscience is not usually possible; however, it could be argued that prevalence of certain “sociotechnical imaginaries” (Jasanoff & Kim, 2015) might favour particular outcomes over others. When considering for-profit influences from powerful groups on science and technology, a participatory role of citizens, with critical science literacy, seemed required to bring balances in imaginaries and outcomes. Hence, we advocate youth socio-political activism through science education, while emphasizing examinations of ‘hidden’ problems to better inform decisions. This paper reports on experiences of a high-school science teacher in Greece implementing an activist science education framework in his courses. It examines constructs of students’ ‘micro-sociotechnical imaginaries’ in relation to different commodities and socioscientific issues they are examining. We argue that in constructing their imaginaries, students and their teacher negotiated their prioritized values, and possible values of other stakeholders. Our research indicates significance of value negotiations in bringing forward desired futures. It also points out to possible merits of sociotechnical imaginaries, on the micro-levels of classrooms, in enabling students and

teachers to construct visions for how they will lead their lives and teaching practices, respectively.

Paper 4: School Science Students Envisaging (A)Biotic Alliances Prioritizing Educated & Researched Values

Larry Bencze, Dave Del Gobbo, Sarah El Halwany, Minja Milanovic*, Nurul Hassan, Jasmine Yeung & Majd Zouda
University of Toronto, *Bishop Strachan School*

Much of our world seems precarious. There are fears, for instance, that humanity is on a ‘precipice’ due to threats from climate change, habitat destruction and species losses, nuclear weaponry and more. Meanwhile, societies seem plagued by ongoing struggles like those to eliminate diseases (e.g., cancer) from manufactured foods, privacy and autonomy threats from surveillance systems, and harms from prescription and illicit drugs. Associated with many such harms are fields of science and technology (S&T). However, scholarship from Science and Technology Studies, cultural studies, et cetera suggest that myriad biotic, abiotic and symbolic entities (‘actants’) — including fields of S&T — are interwoven into a global network (dispositif) largely promoting capitalist goals like individual competitiveness, costs externalization and continuous growth. In this light, fields of S&T education seem to have key responsibilities for educating students about such problematic power relations and preparing them for pro-active citizenship. Results of the facilitated action research project — based on constructivist grounded theory analyses of qualitative data — reported here suggest, indeed, that teenagers may help overcome many S&T-related harms through envisaged material-semiotic alliances if directly-taught, with personalized applications, important power-related concepts (e.g., normalizing power).

Symposium title: Programmatic research on STEM concept formation: Conceptual PlayWorlds as an educational experiment in early years

*Organiser: Marilyn Fleer
Monash University*

Overview Abstract

The international trend to increase engagement in STEM starts early. But studies show little STEM is taught to infants, toddlers and pre-schoolers. Longstanding research identifies teachers who do not feel confident or competent in STEM concepts. In drawing on cultural-historical theory we designed in our PlayLab a series of educational experiments (ARC Laureate Fellowship), where collaborations between teachers and researchers focused on solving this problem. An intervention of a Conceptual PlayWorld was used for researching STEM concept formation and the motives of teachers, families, and early childhood children and girls. This symposium reports on the outcomes of these 4 interrelated studies.

Paper 1: Beyond teacher confidence and competence in STEM: Bringing STEM concepts into play practice

*Marilyn Fleer, Glykeria Fragkiadaki, Prabhat Rai
Monash University*

Decades of research into early childhood teacher confidence and competence in STEM abound. Mostly what is reported is that teachers do not have the background discipline knowledge of STEM concepts and thereby lack confidence to teach in this area. The net effect is a worryingly limited amount of science being taught in the early childhood period. This paper proposes a different approach to conceptualising teacher confidence and competence in science through a theoretically informed study that gives new directions into how to solve the pressing problem of increasing the amount of science taught in play-based settings. Teacher participation in a face-to-face and on-line PD program over 10 weeks was digitally documented and analysed. Using the concepts from cultural-historical theory, the results show four types of crises emerged in the PD program. Through a model known as a Conceptual PlayWorld, new conditions for practice change were created to amplify STEM concepts in play-based settings. The major conclusion was that it is not teacher knowledge of concepts that is preventing science teaching, but rather it is how to pedagogically bring concepts into play practice to motivate and sustain children's engagement in STEM.

Paper 2: Conditions created by a Conceptual PlayWorld for increasing girls' STEM engagement in early childhood

*Tanya Stephenson, Marilyn Fleer, Glykeria Fragkiadaki
Monash University*

As societal needs change, there is an increasing concern for the participation of girls in STEM. While research has consistently recognized the unintended preferential treatment of boys during STEM teaching, there has been limited change. Gendered interactions influence girls' identity formation from a young age, leading to a decrease in girls' STEM engagement, and the ongoing underrepresentation of women in STEM. It is important to consider the early stages of education to improve this gap. This study explores the motivating conditions created by the Conceptual PlayWorld model for girls' STEM engagement in early childhood. Using the cultural-historical framework and a holistic study design, video observations of interactions within and outside Conceptual PlayWorlds were gathered from 2 preschool teachers and 13 children aged 2.3 - 3.2 years. Findings support previous research regarding the accumulation of microaggressions in free-play settings that position girls away from STEM activity. These are minimised inside the Conceptual PlayWorld due to the changed role of the teacher. It is argued that the possibilities afforded by this model positively shift interactional patterns to create motivating conditions for girls in STEM, allowing both girls and boys the opportunity to have a strong engagement with STEM from the very beginning.

Paper 3: Conceptual PlayWorld@homeLIVE for STEM concept formation: A Digital Educational Experiment

*Prabhat Rai, Marilyn Fleer, Glykeria Fragkiadaki
Monash University*

Luciano Floridi, professor of philosophy and ethics of information at Oxford argued in his book *The Fourth Revolution*, that our world is being integrated into a global 'infosphere' where what we do online and off merge into an 'onlife'. Fleer (2019) conceptualisation of 'digital coadjuvants', echoes similar argument in the context of children's digital engagement. Following a cultural-historical line her argument is digitally amplified practices (named as coadjuvants), support children's development. This paper draws on our recent work at Conceptual PlayLab where we are working with families through Playgroup Victoria's

expansive network to create motivating conditions for children's STEM concept formation in their home settings. The paper emphasises that Conceptual PlayWorld@homeLIVE as an innovative model of practice offers a design principle to use digital artefacts in sustaining and amplifying children's exploration in their imaginary play situation. The data reported in this research was collected using zoom sessions over a period of four weeks with 8 families in Victoria. The data especially reports on the transformative potential for children to imagine and explore together with their caregivers in the Conceptual PlayWorld.

Paper 4: Infants and toddlers' collective STEM concept formation in a Conceptual PlayWorld

*Marilyn Fleer, Glykeria Fragkiadaki, Prabhat Rai
Monash University*

During the very early years, children are extremely curious about the physical, technical, and technological world that surrounds them and this is when fundamental understandings about the world emerge and develop. However, limited empirical research is conducted on how infants and toddlers form STEM concepts and how early childhood educators can support this process in early childhood settings. This study captured how STEM concept formation begins during infancy and develops over toddlerhood and what pedagogical practices can support this process across age. The study is part of Australia's first programmatic study of conceptual play in science, engineering, and technologies. The research design drew on the Conceptual PlayWorld model, a collective form of practice for learning and development through imagination and play. A cohort of 130 children participated in the study. An indicative case example is presented. Digital visual methods were used for data collection and analysis. The findings illustrated children form the concepts in interrelation to the degrees of freedom in their interactions with the physical, technical, technological as well as the social world. What was also found is that using the dominant motive of play teachers can orient children to science and support them to develop a science motive.

Symposium Title: Multi-organisational Collaboration to Develop a Sustainable Model of STEM Professional Learning

*Organiser: Kim Nichols
University of Queensland*

The proposition this symposium explores is that an ecosystems model for STEM learning is needed to positively impact student's engagement in STEM. The four presentations in this symposium revolve around a sustainable model of a community-based STEM professional learning program (PLP) developed through a research collaboration between universities, the Queensland Department of Education (DOE) and the Queensland Museum (QM). The study is part of a larger collaborative ARC project on STEM professional learning for teachers of middle years. This unique confluence of a STEM PLP with its impact on pedagogy, student learning and engagement will be explored through a range of perspectives including those of the researchers, Queensland museum educators, teachers from a case study school and the DOE.

Paper 1: The STEM PLP

*Kim Nichols, Reshma Parveen, Chae Swindell**
*University of Queensland, *Queensland Museum Network*

This part of the symposium explains and explores the STEM PLP. The PLP involved the development of a broad range of collaborative inquiry problem solving STEM resources for middle school science classrooms. This PLP developed through collaboration between researchers, educators and museum scientists brings a unique perspective to STEM inquiry and has the potential to be sustained beyond the project. In this presentation, a museum educator will reflect and share her lived experience of the process and development of the PLP. This presentation will explore the intersectionality of the PLP between the diverse perspectives of educational researchers, scientists and educators. The evolving nature of the PLP will be discussed as well as the implications of the collaboration for sustainable STEM professional learning. A museum educator will share experiences of the development of the PLP resources while the researchers will provide an insight into the impact of problem-solving tasks for students' agentic engagement.

Paper 2: Student Agentic Engagement

Reshma Parveen, Kim Nichols
University of Queensland

In this part of the symposium, the university researchers will explore the theoretical approach to the study based on an ecosystems model (Bronfenbrenner & Morris, 2006) that recognises that teachers are embedded in classrooms in schools within communities and that interactions within and between these can affect students' experiences, engagement, attitudes, and learning. Using empirical data, we will discuss how the collaboration and unique model of STEM PLP problem solving tasks has impacted on student agentic engagement, the translation of students' inner capabilities into meaningful actions for learning. Discourse analysis of student small group inquiry tasks revealed characteristics of agentic engagement including students' offering input, expressing preferences, offering a suggestion or contribution, asking questions, communicating their thinking, solving problems, seeking clarification, generating options and reflecting on their learning. Further analyses of student and teacher talk suggests that these actions can contribute to, modulate, or shift the flow of instruction in the classroom and in this way agentic engagement involves self-regulation, with the associated cognitive and metacognitive benefits. We will discuss how students act as epistemic agents; individuals or groups who take, or are granted, responsibility for learning. Alongside these findings, student survey data shows an improvement in students' attitudes towards science, inquiry and STEM careers.

Paper 3: The Case Study School

*Rose Wood, Mel O'Brien**
*Queensland Department of Education, STEM Team, *Clinton State School*

This project was conducted alongside the Queensland DOE's Advancing STEM in Primary Schools (ASPS) initiative with the Department and with schools participating in this initiative as partners. In this part of the symposium the DOE will discuss intentionality of the ASPS alongside the ARC study in terms of their STEM initiatives for Queensland schools. They

will also highlight the aims, goals and process with its availability of resources for teachers. The DOE perspective of successful case examples from the initiative including a case study school from the ARC project will be explored. Following this, the participating teachers of the PLP the Head of Curriculum (HoC) will elaborate on their experiences with the enactment of the STEM problem solving tasks in their science classroom. They will analyse their contextualized implementation of the PLP's model of inquiry for effective student engagement. The HoC will share their collective endeavor of STEM education and how they modeled the PLP in their school for other teachers. The PLP participating teachers will highlight the contextualization of the STEM problem solving tasks to their classroom. A consistent observation across this school's network of primary teachers is that student engagement was improved, and literacy skills were enhanced through this collaborative study. Furthermore, teachers perceive that their students' individual needs are being accommodated through the STEM inquiry approach. Greater insight into the broader classroom context and teachers' mediation of the students' group problem solving activities will be provided through the teachers' reflection on the enactment of the professional learning in their classroom.

Bronfenbrenner, U., and Morris, P.A. (2006). The bioecological model of human development. In W. Damon and R.M. Lerner (Eds.), *Handbook of Child Psychology, Volume 1: Theoretical Models of Human Development* (6th ed., pp. 793-828). New York: Wiley.

Symposium title: Using immersive virtual reality to enhance learning of science: design and evaluation of science learning and user experiences

*Organiser: Mihye Won
Curtin University*

Overview: Immersive virtual reality (VR) has captured the imagination of many science educators. What can it do for education? Would it really work for *my* students? What does it take to adopt VR or to investigate its educational possibilities? In this symposium, a group of researchers presents (1) what to consider in designing and evaluating immersive virtual reality activities for science learning and (2) what they have found from the design and evaluation of science learning through immersive VR over the last three years.

Discussants: Roy Tasker and David Treagust

Paper 1: Design and evaluation of science learning activities in immersive virtual reality through an immersive learning framework

Mihye Won¹, Dewi Ungu¹, Henry Matovu¹, David Treagust¹, Mauro Mocerino¹, Roy Tasker² & Chin-Chung Tsai³

¹ Curtin University, ² Western Sydney University, ³ National Taiwan Normal University

Immersive virtual reality (VR) is an advanced visualisation system that allows students to jump into a virtual world to interact with real and imagined objects, explore abstract science concepts, discuss their ideas with peers, and construct a deeper understanding. Despite its unique potential, educators are yet to embrace the new medium and explore its educational possibilities systematically. In this presentation, we introduce a framework to guide the design and evaluation of immersive VR for education. The framework is an adaptation of

Dede's (2009) immersion strategies for educational research. It includes technological affordances of immersive VR as the instructional medium (sensory, interactivity and embodied movement), in relation to the integrated learning content (relevancy, agency and challenge) and pedagogical approaches for knowledge construction (guidance and social interactions). As a showcase of how the framework works, we present the design features and the learning activities of an immersive VR learning program (Amazing Snowflakes), then discuss the evaluation of the students' learning within the immersive VR program through a video analysis of 22 first-year university students in relation to students' engagement and learning outcomes.

Paper 2: What Physical Models and Textbook Illustrations Don't Show Us: Students' Exploration of Hydrogen Bonding in Immersive Virtual Reality

Henry Matovu¹, Dewi Ungu¹, Supervisors: Mihye Won¹, David Treagust¹, Mauro Mocerino¹, Roy Tasker² & Chin-Chung Tsai³

¹ Curtin University, ² Western Sydney University, ³ National Taiwan Normal University

Visualising dynamic molecular interactions with existing learning media has proven to be difficult for many students. We investigated how learning activities in a new learning medium--collaborative immersive virtual reality (VR)--helped students improve their understanding of hydrogen bonding between water molecules. Twenty-two first-year university students were paired to go through the learning tasks. Videos of the VR sessions were analysed. Students walked around the molecules or lowered their bodies to change their views of the hydrogen bond formed. The 360-degree views of the molecules and interactivity in the immersive VR environment helped students to understand how the angle and distance between the molecules affected the strength of the bond. Embodied movement, such as rotating and moving molecules, and visual cues in form of changing colours and thickness of the bond helped the students appreciate the dynamic nature of the intermolecular interactions of water. However, without the tactile force feedback as is available in magnetic physical models, students struggled to associate the hydrogen bond with attraction and repulsion between the molecules. Our findings show that collaborative immersive VR supported students' understanding of abstract concepts such as dynamic interactions and spatial relations in molecular systems.

Paper 3: Title: Educational Affordances of Physical Models, Computer Simulation, and Immersive Virtual Reality in Improving Students' Chemistry Learning

Dewi Ungu, Henry Matovu, Supervisors: Mihye Won¹, David Treagust¹, Mauro Mocerino¹, Roy Tasker² & Chin-Chung Tsai³

¹ Curtin University, ² Western Sydney University, ³ National Taiwan Normal University

Visualising molecular structures and interactions remains a challenge in understanding and applying chemistry concepts, such as intermolecular forces. Eleven pairs of first-year university students used three learning media (physical models, computer simulation, and immersive virtual reality) to learn the hydrogen bonds between water molecules. Using the immersion strategies framework adapted from Dede (2009), session videos and pre-/post-interviews were analysed to evaluate students' learning in each media. Students learned different concepts in each media, despite similar learning tasks. The magnetic model's tactile nature engaged students' attention to the repulsive and attractive forces between water molecules. The computer simulation's interactive animations and energy graphs directed students' attention to the hydrogen bond's optimum angle and length. The 3-D virtual environment and embodied interactions within immersive virtual reality led students

to connect the spatial arrangement of hydrogen bonds in ice to the six-fold symmetry of snowflakes. Our findings showed that students' learning of chemistry concepts such as hydrogen bonding was influenced by how the affordances of each learning media were aligned with the learning content and pedagogical approaches. The immersion strategies framework was instrumental in analysing students' learning, and it could inform the design of learning activities in both non-immersive and immersive learning media.

Dede, C. (2009). Immersive Interfaces for Engagement and Learning. *Science*, 323(5910), 66. <https://doi.org/10.1126/science.1167311>