asiahpst2016.pusan.ac.kr

ASIA History, Philosophy of Science & Science Teaching 2016 Conference

PUSAN NATIONAL UNIVERSITY, BUSAN, KOREA
DECEMBER 15-18, 2016

INQUIRY IN SCIENCE AND SCIENCE EDUCATION:
Historical, Philosophical and Pedagogical Dimensions

ORGANIZED BY
PUSAN NATIONAL UNIVERSITY
RESEARCH INSTITUTE for SCIENCE EDUCATION

SUPPORTED BY
부산대학교
PUSAN NATIONAL UNIVERSITY

Presentations by Categories at Asia HPST 2016 Conference

PLENARY	KEYNOTE	ORAL	POSTER	WORKSHOP	SYMPOSIUM	TOTAL
1	4	29	13	3	5	55

The conference proceedings is printed by 2016 Pusan National University Academic Conference Support Program.
이 학술발표논문집은 2016학년도 부산대학교 학술행사개최 경비지원 사업의 일환으로 일부 지원을 받아 발간되었음.
The conference proceedings is printed by financial support of Research Institute for Science Education, Pusan National University.
이 학술발표논문집은 부산대학교 과학교육연구소 행사개최 경비지원의 일환으로 일부 지원을 받아 발간되었음.

Asia History, Philosophy of Science and Science Teaching 2016 Conference

Inquiry in Science and Science Education: Historical, Philosophical and Pedagogical Dimensions

December 15-18, 2016, Pusan National University, Busan, Korea

• Proceedings of Asia History, Philosophy of Science and Science Teaching 2016 Conference

Printed: December 15, 2016

Conference Official Webpage: http://asiahpst2016.pusan.ac.kr
Organizer: Research Institute for Science Education, Pusan National University, http://sciedu.pusan.ac.kr
Editors-in Chief: Youngmin Kim & Hae-Ae Seo, Pusan National University
Secretary General: Jina Yoon, Pusan National University

Address: 2, Busandaehak-ro 63beon-gil, Geumjeong-gu,
Busan, 46241, KOREA
Research Institute for Science Education, Pusan National University [Tel: +82.51.510.1877]

Printing Company: Eutteum-sa

Address: 7, Busandaehak-ro 63beon-gil, Geumjeong-gu,
Busan, Republic of KOREA [Tel: +82.51.515.9700]

• Organized by Research Institute for Science Education, Pusan National University

• Sponsored by Pusan National University

CONTENTS

WELCOME ADDRESS

Welcome to Asia HPST 2016 Conference and Busan

All of conference participants,

Welcome to Pusan National University for the Asia History, Philosophy of Science and Science Teaching 2016 Conference.

This is the third time that an Asia country organizes a HPST conference after the first IHPST conference in Seoul, Korea in October 2012 and the second one in Taipei, Taiwan, December 2014. It is our great honor that Busan holds this Asia HPST conference. Busan is the second largest city in Korea. Its deep harbor and gentle tides have allowed it to grow into the largest container handling port in the country and the fifth largest in the world. The city's natural endowments and rich history have resulted in Busan's increasing reputation as a world class city of tourism and culture, and it is also becoming renowned as an international convention destination.

The theme of the conference is "Inquiry in Science and Science Education: Historical, Philosophical and Pedagogical Dimensions." It is hoped that two academic traditions, the history and philosophy of science and science education, are meaningfully and truly integrated in the conference through active exchange of ideas, research results and expertise of the both sides.

We sincerely hope that this Asia HPST Conference will be a platform where one can share research interests and build relationships with colleagues. We warmly welcome you all in Busan in December 2016.

On behalf of the conference committee, we want to thank all plenary and keynote speakers, paper presenters, and all our colleagues for your great contribution to this conference.

Thank you.

Kim, Youngmin
Conference Chair, the Organizing Committee
Asia HPST 2016 Conference
Professor, Department of Physics Education,
Pusan National University, Korea

Seo, Hae-Ae
Conference Chair, the Organizing Committee
Asia HPST 2016 Conference
Professor, Department of Biology Education,
Pusan National University, Korea

GENERAL INFORMATION

OVERVIEW

- Theme
  Inquiry in Science and Science Education: Historical, Philosophical and Pedagogical Dimensions
- Conference dates
  December 15-18, 2016
- Venue
  Pusan National University, Busan, Korea

COMMITTEE

CONFERENCE COMMITTEE

- Chairs

  Kim, Youngmin, Pusan National University
  Seo, Hae-Ae, Pusan National University

- Members

  Sim, Jae-Ho, Pusan National University
  Nam, YounKyeong, Pusan National University
  Kim, Ji Na, Pusan National University
  Nam, Jeonghee, Pusan National University
  Song, Sung-Su, Pusan National University
  Park, Young-Shin, Chosun University
  Park, Jongwon, Chonnam National University
  Song, Jinwoong, Seoul National University
  Martin, Sonya, Seoul National University
  Park, Jongseok , Kyungpook National University

SUPPORTERS and SPONSOR

- Organizer

  Research Institute for Science Education,
  Pusan National University

- Supporters

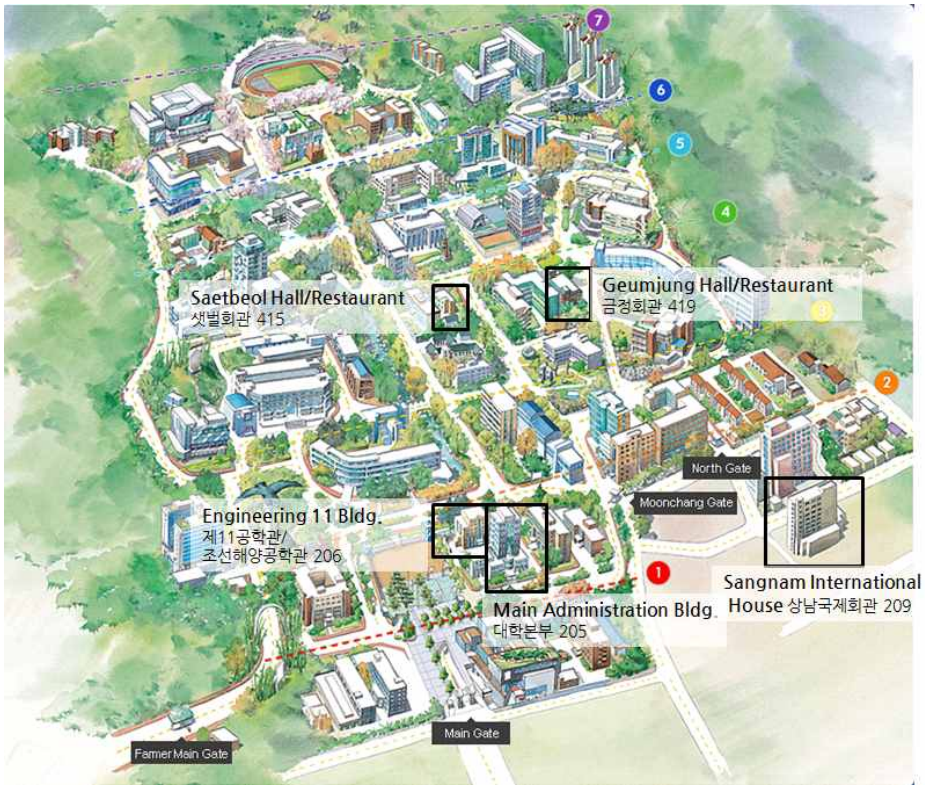
  East-Asian Association for Science Education
  The Korean Association for Science Education
  The Korean Society of Elementary Science Education
  The Korean Society for the Philosophy of Science
  The Korean History of Science Society

- Sponsor

  Pusan National University

VENUE / MAP

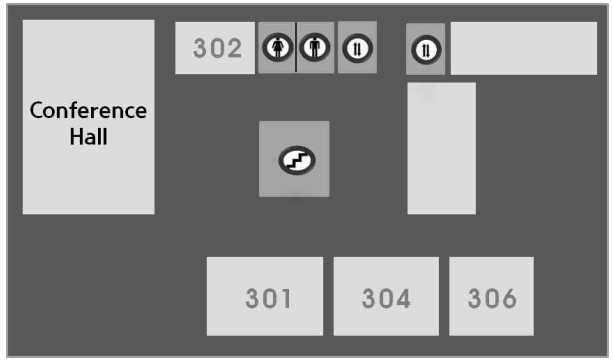
Pusan National University CAMPUS MAP



FLOOR PLAN

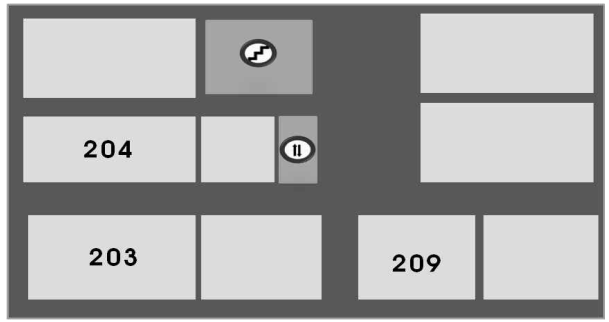
Main Administration Building
Building # 205
부산대학교 대학본부

- Registration
- Plenary, Keynotes
- Pre-conference Workshop, Poster Presentation



Engineering 11 Building
Building # 206
제11공학관-조선해양공학관

- Oral Presentation
- Symposium
- Pre-conference Workshop



Sangnam International House
Building # 209
상남국제회관

- Gala Dinner
- Hotel Accommodations

PROGRAM AT GLANCE

Thursday, December 15, 2016

09:30-16:30	Registration		Conference Hall
	PRE-CONFERENCE WORKSHOP 1		Conference Hall
10:30-12:30	Researching and publishing in HPS&ST Matthews, Michael, University of New South Wales, Australia		
12:30-14:00	Lunch on your own		
	PRE-CONFERENCE WORKSHOP 2-1 Conference Hall	**PRE-CONFERENCE WORKSHOP 2-2** Rm 209	
14:00-16:00	An empirical practice of science inquiry from POE to POE2C Chen, Nelson, National Science and Technology Museum, Taiwan	Making drone and STEAM Kim, Jaekwon, Moonsu High School, Korea	
16:00-16:30	Beverages and Break		
16:30-16:45	Opening Ceremony: Opening Address, Congratulatory Address		Conference Hall
	PLENARY SESSION		Conference Hall
16:45-17:45	Scientific inquiry, education and Feng Shui Matthews, Michael, University of New South Wales, Australia		
18:00-	Opening Reception		Conference Hall

Friday, December 16, 2016

	ORAL PRESENTATION 1		
09:00-10:30	Session A Rm 203	Session B Rm 204	Session C Rm 209
	1A1 | Rachmatullah, Arif Kangwon National University, Indonesia	1B1 | Seo, Hae-Ae Pusan National University, Korea	1C1 | Jho, Hunkoog Dankook University, Korea
	1A2 | Kang, Nam-Hwa Korea National University of Education, Korea	1B2 | Kenklies, Karsten University of Strathclyde, UK	1C2 | Park, Wonyong Seoul National University, Korea
	1A3 | Lay, Ah-Nam National University of Malaysia, Malaysia	1B3 | Oliver, J. Steve University of Georgia, USA	1C3 | Bansal, Deepika University of Delhi, India
10:30-11:00	Beverages and Break		
	KEYNOTE SESSION 1		Conference Hall
11:00-12:00	Genetic determinism in the genetics curriculum: An experimental test of the effects of Mendelian and Weldonian emphases Radick, Gregory, University of Leeds, UK		
12:00-13:30	Lunch		
	KEYNOTE SESSION 2		Conference Hall
13:30-14:30	21st century humanism for science education: A view from philosophy of science Lee, Sangwook, Hanyang University, Korea		
14:30-15:00	Beverages and Break		
	ORAL PRESENTATION 2		
15:00-16:30	Session A Rm 203	Session B Rm 204	
	2A1 | Baykal, Ali Bahcesehir University, Turkey	2B1 | Wong, Cindy Chyee Chen National University of Malaysia, Malaysia	
	2A2 | Khatoon, Sufiana National University of Modern Languages, Pakistan	2B2 | Mun, Kongju Ewha Womans University, Korea	
	2A3 | Belland, Brian Utah State University, USA	2B3 | Kim, Chan-Min University of Georgia, USA	
16:30-17:00	Beverages and Break		
	POSTER PRESENTATION		Conference Hall
17:00-18:00	P01 | Wang, Jing-Ru National Pingtung University, Taiwan	P08 | Ishikawa., Satoko Osaka Kyoiku University, Japan	
	P02 | Kang, Eugene Pusan National University, Korea	P09 | Shin, Sein Chonbuk National University, Korea	
	P03 | Yoo, Jungsook Ewha Womans University, Korea	P10 | Lee, Sangeui Kangwon National University, Korea	
	P04 | Kim, Mikyoung Ewha Womans University, Korea	P11 | Bang, Sin Young Pusan National University, Korea	
	P05 | Zainudin, Suhanna National University of Malaysia, Malaysia	P12 | Kim, Yi Young Pusan National University, Korea	
	P06 | Ha, Minsu Kangwon National University, Korea	P13 | Ham, Junghwa Pusan National University, Korea	
	P07 | Rhee, Hyang-yon Ewha Womans University, Korea		
18:00-	**Partnership for International Exchanges and Cooperation**		

PROGRAM AT GLANCE

Saturday, December 17, 2016

	ORAL PRESENTATION 3		
09:00-10:30	Session A Rm 203	Session B Rm 204	
	3A1 | Park, Jee-Young Seoul National University, Korea	3B1 | Bae, Junghee Pusan National University, Korea	
	3A2 | Hammann, Marcus Westfälische Wilhelms Universität Münster, Germany	3B2 | Park, Eunjung Sookmyung Women's University, Korea	
	3A3 | Cheong, Young Wook Seoul National University, Korea	3B3 | Sun, Yongping Inner Mongolia Normal University, China	
10:30-11:00	Beverages and Break		
	KEYNOTE SESSION 3		Conference Hall
11:00-12:00	The relevance of social epistemology for science education: A theoretical and historical case Rowbottom, Darrell, Lingnan University, Hong Kong		
12:00-13:30	Lunch		
	KEYNOTE SESSION 4		Conference Hall
13:30-14:30	Modern physics education for the masses Kim, Chan-Ju, Ewha Womans University, Korea		
14:30-15:00	Beverages and Break		
	ORAL PRESENTATION 4		**STEAM Symposium**
15:00-17:00	Session A Rm 203	Session B Rm 204	Session C Rm 209
	4A1 | Park, Jongwon Chonnam National University, Korea	4B1 | Kang, Juwon Pusan National University, Korea	4C1 | Park, HyunJu Chosun University, Korea
	4A2 | Kim, Min Kyong Chonnam National University, Korea	4B2 | Choi, Jin-young Daejeon Jeil High School, Korea	4C2 | Kim, Mijung University of Alberta, Canada
	4A3 | Gim, Jinyeong Seoul National University, Korea	4B3 | Kim, Hyung-Uk Imdong Elementary School, Korea	4C3 | Chu, Hye-eun Macquarie University, Australia
	4A4 | Lai, Bo-Chi Da-Yeh University, Taiwan	4B4 | Chen, Ying-chi Arizona State University, USA	4C4 | Kim, Seongman Sasang High School, Korea
			4C5 | Kim, Youngmin Pusan National University, Korea
17:00-17:30	Closing Ceremony		Conference Hall
18:00-20:00	Gala Dinner		Sangnam International Hall

Sunday, December 18, 2016

All day	Cultural Tours
	CT1 | Dynamic Busan City Tour by Bus http://tour.busan.go.kr/eng/index.busan
	CT2 | Busan National Science Museum http://www.sciport.or.kr/eng/index.do
	CT3 | Korea National Maritime Museum https://www.knmm.or.kr/eng/main/main.aspx
	CT4 | Busan Museums http://english.busan.go.kr/museum/Main.bs
	CT5 | Geumjung Mt. and Temple Hiking

PROGRAM TABLE

PLENARY & KEYNOTES			
Plenary	Scientific inquiry, education and Feng Shui	p12	16:45-17:45 Dec 15
	Matthews, Michael, University of New South Wales, Australia		Conference Hall
Keynote 1	Genetic determinism in the genetics curriculum: An experimental test of the effects of Mendelian and Weldonian emphases	p24	11:00-12:00 Dec 16
	Radick, Gregory University of Leeds, UK		Conference Hall
Keynote 2	21st century humanism for science education: A view from philosophy of science	p28	13:30-14:30 Dec 16
	Lee, Sangwook, Hanyang University, Korea		Conference Hall
Keynote 3	The relevance of social epistemology for science education: A theoretical and historical case	p31	11:00-12:00 Dec 17
	Rowbottom, Darrell, Lingnan University, Hong Kong		Conference Hall
Keynote 4	Modern physics education for the masses	p44	13:30-14:30 Dec 17
	Kim, Chan-Ju Ewha Womans University, Korea		Conference Hall
PRE-CONFERENCE WORKSHOPS			
Workshop	Researching and publishing in HPS&ST	p48	10:30-12:30 Dec 15
1	Matthews, Michael, University of New South Wales, Australia		Conference Hall
Workshop	An empirical practice of science inquiry from POE to POE2C	p49	14:00-16:00 Dec 15
2-1	Chen, Nelson, National Science and Technology Museum, Taiwan Park, Young-Shin, Chosun University, Korea		Conference Hall
Workshop	Making drone and STEAM	p50	14:00-16:00 Dec 15
2-2	Kim, Jaekwon, Moonsu High School, Korea		Rm 209
ORAL PRESENTATIONS			
1A1	Indonesian pre-service biology teacher's evolutionary knowledge and reasoning patterns	p52	09:00-09:30 Dec 16
	Rachmatullah, Arif, Kangwon National University, Indonesia Nehm, Ross, Stony Brook University, USA Ha, Minsu, Kangwon National University, Korea Roshayanti, Fenny, University of PGRI Semarang, Indonesia		Rm 203
1A2	Teachers' conceptions of models and modeling in science and science teaching: Ontological and epistemological analysis	p53	09:30-10:00 Dec 16
	Kang, Nam-Hwa, Korea National University of Education, Korea		Rm 203
1A3	Learning chemistry through designing digital games	p53	10:00-10:30 Dec 16
	Lay, Ah-Nam, National University of Malaysia, Malaysia Osman, Kamisah, National University of Malaysia, Malaysia		Rm 203
1B1	South Korean teachers' conceptions related to the genetic determinism of human performances	p55	09:00-09:30 Dec 17
	Seo, Hae-Ae, Pusan National University, Korea Castéra, Jérémy, Aix-Marseille University, France Clément, Pierre, Aix-Marseille University, France		Rm 204
1B2	Bildung in higher science education. A new approach for postgraduate teaching	p55	09:30-10:00 Dec 16
	Kenklies, Karsten, University of Strathclyde, UK		Rm 204
1B3	Integrated science curricula: A consideration of history in light of the NGSS	p56	10:00-10:30 Dec 16
	Oliver, J. Steve, University of Georgia, USA		Rm 204
1C1	An interpretation of quantum mechanics about surrealist paintings: The case of Rene Magritte	p57	09:00-09:30 Dec 16
	Jho, Hunkoog, Dankook University, Korea		Rm 209
1C2	Scientific pluralism as a key epistemic value for the practice turn in science education	p57	09:30-10:00 Dec 17
	Park, Wonyong, Seoul National University, Korea Song, Jinwoong, Seoul National University, Korea		Rm 209
1C3	Do feminist critiques of science matter in science education?	p58	10:00-10:30 Dec 17
	Bansal, Deepika, University of Delhi, India		Rm 209
2A1	What do science and math teachers think how they think?	p59	15:00-15:30 Dec 17
	Baykal, Ali, Bahcesehir University, Turkey		Rm 203
2A2	Dilemma of teaching science in Pakistan at primary school level: Problems and prospects	p59	15:30-16:00 Dec 16
	Khatoon, Sufiana, National University of Modern Languages, Pakistan Gulnaz, Rani, Government Polytechnic Institute for Women H-8/1, Islamabad, Pakistan		Rm 203
2A3	New directions for development of and research on computer-based scaffolding emanating from meta-analyses of scaffolding	p60	16:00-16:30 Dec 16
	Belland, Brian, Utah State University, USA Walker, Andrew, Utah State University, USA Kim, Nam Ju, Utah State University, USA Piland, Jacob, Utah State University, USA		Rm 203

PROGRAM TABLE

ORAL PRESENTATIONS			
2B1	Beyond classroom boundaries, unlocking science learning among indigenous learners in Malaysia	p62	15:00-15:30 Dec 16
	Wong, Cindy Chyee Chen, National University of Malaysia, Malaysia Osman, Kamisah , National University of Malaysia, Malaysia		Rm 204
2B2	Understanding of interest in science learning based on John Dewey's concept of interest	p62	15:30-16:00 Dec 16
	Mun, Kongju, Ewha Womans University, Korea		Rm 204
2B3	Use of robotics in preparing teachers to teach science	p63	16:00-16:30 Dec 16
	Kim, Chanmin, University of Georgia, USA Yuan, Jiangmei, University of Georgia, USA Vasconcelos, Lucas, University of Georgia, USA Hill, Roger. B, University of Georgia, USA		Rm 204
3A1	Science education at crossroads: Socio-scientific issues and education	p64	09:00-09:30 Dec 17
	Park, Jee-Young, Seoul National University, Korea Ma, Eunjeong, Pohang University of Science and Technology, Korea		Rm 203
3A2	Will science solve all our genuine problems?	p64	09:30-10:00 Dec 17
	Hammann, Marcus, Westfälische Wilhelms Universität Münster, Germany Konnemann, Christiane, Westfälische Wilhelms-Universität Münster, Germany Asshoff, Roman, Westfälische Wilhelms Universität Münster, Germany		Rm 203
3A3	Theoretical investigation on the merit of conceptual blending in comparison with metaphor and analogy in science education	p65	10:00-10:30 Dec 17
	Cheong, Yong Wook, Seoul National University, Korea		Rm 203
3B1	Effect of science drama program on creativity and character education for science gifted	p66	09:00-09:30 Dec 17
	Bae, Junghee, Pusan National University, Korea		Rm 204
3B2	Revisit Galileo and science in his term	p66	09:30-10:00 Dec 17
	Park, Eunjung, Sookmyung Women's University Korea		Rm 204
3B3	Francis Crick and his influence on genetic code research in China	p67	10:00-10:30 Dec 17
	Sun, Yongping, Inner Mongolia Normal University, China		Rm 204
4A1	The effect of background knowledge and metaphysical belief on interpreting quantitative data	p68	15:00-15:30 Dec 17
	Park, Jongwon, Chonnam National University, Korea Lee, Insun, Chungbuk National University, Korea Kim, Ikgyun, Chungbuk National University, Korea		Rm 203
4A2	College students' understanding about the metaphysical meaning of scientific concepts/ phenomena and their perception of the importance of it in their everyday life and teaching science	p68	15:30-16:00 Dec 17
	Kim, Min Kyoung, Chonnam National University, Korea Park, Jongwon, Chonnam National University, Korea		Rm 203
4A3	A simple experiment and embarrassed instructions: Boyle's quantitative experiment, explanation, and mechanical philosophy	p69	16:00-16:30 Dec 17
	Gim, Jinyeong, Seoul National University, Korea		Rm 203
4A4	The historical perspectives of species concept development is the basement of modified mechanism for biological species concept	p69	16:30-17:00 Dec 17
	Lai, Bo-Chi, Da-Yeh University, Taiwan		Rm 203
4B1	The development of an instrument for measuring the creative engineering problems solving propensity for STEAM	p71	15:00-15:30 Dec 17
	Kang, Ju-Won, Pusan National University, Korea Nam, Younkyeong, Pusan National University, Korea		Rm 204
4B2	The development and effect of learner-centered interactive STEAM program based on movie contents 'the Martian'	p71	15:30-16:00 Dec 17
	Choi, Jin-young, DaeJeon Je-il High School, Choi, Su-young, Hannam University, Korea Shin, Hyun-sook, DaeJeon Je-il High School, Kim, Chun-bong, DaeJeon Je-il High School, Korea, Lee, Young-bae, DaeJeon Je-il High School, Kim, Jin-young, DaeJeon Je-il High School, Korea Eom, Tae-hyeon, DaeJeon Je-il High School, Yoon, Ma-byong, Jeonju University, Korea		Rm 204
4B3	The systems thinking based STEAM program: Making creative water clock	p72	16:00-16:30 Dec 17
	Kim, Hyung-Uk, Im Dong Elementary School, Korea		Rm 204
4B4	Enhancing pre-service science teachers' epistemic understanding of arguments through a science inquiry activity	p73	16:30-17:00 Dec 17
	Chen, Ying-Chih, Arizona State University, USA Nam, Younkyeong, Pusan National University, Korea		Rm 204
4C1	STEAM education in Korea	p74	15:00-15:25 Dec 17
	Park, Hyunju, Chosun University, Korea Baek, Yoon Su, Yonsei University, Korea Kim, Youngmin, Pusan National University, Korea		Rm 209
4C2	STEM education in Canada: Some initiatives and challenges	p74	15:25-15:50 Dec 17
	Kim, Mijung, University of Alberta, Canada		Rm 209

PROGRAM TABLE

ORAL PRESENTATIONS			
4C3	Arts integrated STEM education in Australia Chu, Hye-Eun, Macquarie University, Australia	**p75**	**15:50-16:15 Dec 17** Rm 209
4C4	M-STEAM program based on modeling management Kim, Seongman, Sasang High School, Korea Lee, Hyeounrok, Sasang High School, Korea	**p75**	**16:15-16:40 Dec 17** Rm 209
4C5	Project for globalization of STEAM education of Korea Kim, Youngmin, Pusan National University, Korea Baek, Yoon Su, Yonsei University, Korea Park, Hyunju, Chosun University, Korea Kwon, Hyuksoo, Kongju National University, Korea	**p76**	**16:40-17:00 Dec 17** Rm 209
POSTER PRESENTATIONS			**17:00-18:00 Dec 16**
P1	A meta-analysis of inquiry-based instruction on student learning outcomes in Taiwan Wang, Jing-Ru, National Pingtung University, Taiwan		**p78**
P2	Routes of secondary-school science textbooks from western countries to Korea Kang, Eugene, Pusan National University, Korea		**p78**
P3	Exploration about the relationship between science & engineering university students' the career choice factors and their prior experiences of science activities before college Yoo, Jungsook, Ehwa womans university, Korea Rhee, Hyang-yon, Ehwa womans university, Korea		**p79**
P4	The history of measurement in Korean and western cultures Kim, Mikyoung, Ewha Womans University, Korea Yang, Tai Gil, Daekyeong Middle School, Korea Lee, Chae Yeon, Demonstration Middle School, Ewha Womans University, Korea Yoo, Hyuk-Keun, Demonstration Middle School, Ewha Womans University, Korea Lee, Je Sung, Choongam Middle School, Korea Choi, Young-Jin, Ewha Womans University, Korea Shin, Dong-Hee, Ewha Womans University, Korea		**p79**
P5	The level of reflection writings toward science teaching with lesson study approach Zainudin, Suhanna, National University of Malaysia, Malaysia Iksan, Zanaton, National University of Malaysia, Malaysia Othman, Mohd Izwan, Malaysia Ministry of Education, Malaysia		**p80**
P6	Relationships among academic, religious, and socio-economic variables Ha, Minsu, Kangwon National University, Korea Rachmatullah, Arif, Kangwon National University, Indonesia		**p81**
P7	Educational shift of science and technology ethics in the national science curricula of Korea from the 7th in 1997 to the 2015 curriculum revision Rhee, Hyang-yon, Ewha Womans University, Korea		**p81**
P8	SSI in Japan: The lack of "uncertainty" as NoS Ishikawa, Satoko, Osaka Kyoiku University, Japan		**p82**
P9	Exploring Korean medical students' various perceptions on mind-body problem: Empirical findings from latent class analysis Shin, Sein, Chonbuk National University, Korea Lee, Jun-Ki, Chonbuk National University, Korea Yoo, Hyo-Hyun, Chonbuk National University, Korea Rachmatullah, Arif, Kangwon National University, Korea Ha, Minsu, Kangwon National University, Korea		**p82**
P10	Korean and Indonesian pre-service science teacher's attitude towards environment Lee, Sangeui, Kangwon National University, Korea Park, Eunju, Kangwon National University, Korea Rachmatullah, Arif, Kangwon National University, Indonesia Ha, Minsu, Kangwon National University, Korea Lee, Junki, Chonbuk National University, Korea		**p83**
P11	Elementary school student's recognition by open inquiry Bang, Sin Young, Pusan National University, Korea Kim, Hyo-Nam, Korea National University of Education, Korea		**p83**
P12	The effects of the middle school students' conceptual changes on buoyancy by experimental videos for demonstration using a quantitative method and a qualitative method Kim, Yi Young, Pusan National University, Korea Kim, Ji Na, Pusan National University, Korea		**p84**
P13	The effects of the application of backward course design in elementary school science on 'biological and environmental' section Ham, Junghwa, Pusan National University, Korea Sim, Jaeho, Pusan National University, Korea		**p84**

PLENARY

▪ Plenary 16:45-17:45 / Dec. 15, 2016 / Conference Hall

Scientific inquiry, education and Feng Shui

Matthews, Michael R., University of New South Wales, Australia
✉ m.matthews@unsw.edu.au

Abstract

The paper documents how feng shui belief and practice is a significant worldview in Chinese and south-east Asian cultures, and how it has an increasing commercial and personal presence in Western cultures. It documents the almost total neglect of feng shui in educational and philosophical literature, especially in accounts of pseudoscience and of 'alternative sciences'. A brief account of the history of feng shui is given, and special attention is paid to two early encounters between feng shui and Western science and its worldview: first, the Jesuit Priest Matteo Ricci (1552-1610) and second, the Protestant missionary Ernst Johann Eitel (1838-1908). It elaborates efforts at cultural modernization in twentieth century China including the Communist Party's efforts, and how these sought to excise feng shui from personal and cultural life. Debate over the possibility of demarcating science from pseudoscience is examined and arguments are given for regarding feng shui as a pseudoscience. The claim is made that it is a responsibility of education, specifically science education, to engage with and promote the refinement of students' worldviews. This is a contribution of science education to cultural health.

Introduction

Feng shui a system of beliefs and practices originating some three to four thousand years ago that is concerned with identifying, charting, and utilizing the supposed all-encompassing flow of chi or qi, the putative universal

life force, so that people's lives and their habitat can be brought into harmony with it, made more natural, and so improved. It is a worldview and is a significant feature of Chinese and south-east Asian cultures. But it has long migrated from Asia and has an increasing international commercial and personal presence. Feng shui is a growth industry, yet it is a neglected topic in science education. It is also ignored in most philosophical discussions of pseudoscience and the demarcation dispute; discussions where it might be expected to be mentioned and used as a case study.

This neglect is an enigma as feng shui is a worldview about the constitution of the world and the ways in which humans can most harmoniously live in the world. Unlike many comparable worldviews, feng shui is explicitly claims to be scientific. The whole theory and practice of feng shui revolves around the identification and utilisation of universal energy, or chi, that circulates in a defined manner through nature and through specific meridians in people's bodies where there are 600+ nodes that can be manipulated by acupuncture. Feng shui occupies just one sector on the wide spectrum of chi-based Eastern beliefs, therapies and practices. Over two or three thousand years, under different philosophical and cultural influences, many versions of fundamental chi-based practice have evolved and cemented their place. Along with feng shui, others in the spectrum are: Qi Gong, Falun Gong, Tai Chi, and Jin Shin Jyutsu.
Questions examined in this talk will be:

What characterises feng shui as a world view?
What identifies feng shui as a pseudoscience?
Is feng shui a detrimental social practice?
How can examination of feng shui as a pseudoscience contribute to knowledge of the nature of science?
Can the appraisal of feng shui promote a scientific habit of mind?
Can the historical and philosophical examination of feng shui in classrooms contribute to the cultural health of society?

The Cultural Contribution of Science Education

Education promotes the well-being of society. All school subjects make their own contribution to this overall social well-being. Apart from obvious areas of personal knowledge, clear thinking and psychological health, science education, and the culture-wide science literacy it promotes, can make contributions to the cultural health of societies by clarifying and appraising worldviews.
Jon Miller, who for decades has researched science literacy and public understanding of science, well stated this point:

In addition to understanding basic scientific constructs, it is important for citizens to recognize pseudoscientific constructs that seek to be recognized as scientific. Astrology is a good example. Since 1988, national samples of US adults were asked whether they though that astrology was "very scientific, sort of scientific, or not at all scientific." Throughout this period, approximately 60 percent of US adults recognized astrology as being not at all scientific. (Miller 2004, p.278) Which means that 40% think astrology is or could be scientific!

Academic Neglect of Feng Shui

Given the multiple-millions of feng shui believers in Asia and increasingly beyond Asia, and its immense social, commercial and personal impact, it is noteworthy that there has been so little appraisal, critical or otherwise, of feng shui in philosophical or educational literature. A whole raft of popular and highly regarded books devoted to pseudoscientific belief systems simply fail to mention feng shui. And, revealingly, feng shui does not appear in the 35-chapter, 472-page Chinese Studies in the History and Philosophy of Science and Technology (Dainian & Cohen 1996). If feng shui were to be treated seriously and critically by historians and philosophers of science, this last Chinese-based anthology would be a natural home for such examination, but there is no such examination.

This neglect is noteworthy as Asian countries famously top the world in school science achievement: Singapore, South Korea, Hong Kong, Japan, Shanghai and other Chinese centres define the gold standard in the field. These countries are also the gold medallists in feng shui belief. The concurrence of high science achievement along with widespread feng shui belief does raise the question: To what extent does science education promote a scientific habit of mind? Which invites a further question: Can belief in feng shui theory and practice be compatible with a scientific habit of mind?

Chi and Feng Shui

Feng shui had its origin three-to-four thousand years ago in China as part of a family of cosmological worldviews in which an all-pervasive life force, or energy, known as qi (or chi) bound together nature and man. Before its articulation as a metaphysical cosmology, it was merely the collective, passed-down commonsense of Chinese and other cultures that needed to attend to environmental realities in order to sow, harvest, herd, build houses and villages, and live safely with whatever comfort could be garnered. Feng shui translates literally as 'wind water'. It is not surprising that this became the name for the all-encompassing cosmological system, as wind and water were the primeval forces that formed landscapes and governed much of life. A proper, historically-informed understanding of chi (qi) is clearly a major challenge, yet Stephen Field, a translator of Guo's classic says that 'Qi is the sine qua non for any discussion of feng shui' (Guo 2001). So, this challenge cannot be avoided.

An authoritative modern text on Chinese Philosophy written by Zhang Danian, from Beijing University Philosophy Department, devotes a chapter to Chi. The book provides an informative listing of scores of representative and influential Chinese chi beliefs from ancient times to the present. Zhang

surmises the tradition of qi beliefs as follows:
Qi is the original material out of which all things are formed by coagulation.
Qi has breadth and depth and can be spoken of.
Qi is contrasted with the mind. It exists independent of the mind.
Qi can move. Indeed, it is normally in a state of flux and transformation. (Zhang 2002, p.63)

And he adds:
Hence, what Chinese philosophy says about qi is basically the same as what Western philosophy says about matter. The Chinese theory, however, is distinctive on two counts:
Qi is not impenetrable; rather, it penetrates all things;
Qi is intrinsically in a state of motion and is normally in flux. (Zhang 2002, p.63) Identifying with science, and seeking the public esteem and legitimation that it brings, is a two-edged sword for feng shui: the more explicitly its advocates tout its scientificity, the more pressing is the need for scientific-philosophical appraisal of the worldview and associated geomantic practices. The enigma is that this has not happened.

Feng Shui Practice

Feng shui was never just a worldview; from the beginning, it was connected to practice, to decision making about where to live, the configuration of domestic and government buildings, lifestyles, and how to identify auspicious times and foretell futures. Feng shui has always had a significant geomantic dimension, a 'fortune-telling' dimension; it was an Eastern version of astrology that was so routine across the entire ancient and medieval worlds, and that still lingers in the modern world, both East and West. Three thousand years later, for millions of people, feng shui dictates major commercial and domestic construction decisions as well as the proper internal arrangement of offices, homes, kitchens, gardens, furniture and decorations. And it designates auspicious dates as well as days of misfortune.

The universal distribution and flow of chi not only dictates the best-placement of structures to harmonize them with local energy flows, but chi also internalizes and determines the health and well-being of people. Chi is at the heart of all Traditional Chinese Medicine; it purportedly flows along numerous meridians in the body and any interruption to this orderly flow results in pain, illness and disease. Ken Tobin, who before 'moving on', was a world-leader of the constructivist movement in science education and the recipient of numerous education research prizes (Tobin 2000), has embraced chi-related medical practice, saying:

The underlying theory relates to Qi, universal energy, and its flows through the body. In the case of humans there are 26 pairs of safety energy locks (SELs) through which Qi flows, providing the life source to the body … When a body is disharmonized, energy can be blocked at or close to the SELs, thereby disrupting one or more of the flows needed to distribute the life force to different parts of the body. (Tobin 2015)

Commercial Feng Shui

Feng shui belief and practice is wide-spread in China, in Chinese-influenced Asia, and over the past fifty years, increasingly in the West. A study of feng shui in Korea commenced with the statement: 'The importance of geomancy in understanding the East Asian cultural landscape and cultural ecology is difficult to overemphasize' (Yoon 2006, p.xiii). Hong Kong is the epicentre of the feng shui industry. One scholar writes that: 'Nowhere in the world is feng shui so intensely integrated into every aspect of social, religious and commercial life as in Hong Kong' (Bruun 2008, p.136).

In the Feng Shui Stakes, Hong Kong is closely challenged by Taiwan. In 2004 the Taipei Times (17 October 2004) estimated that there were 30,000 feng shui practitioners in Taiwan. And they are kept busy. After an especially bad train derailment in Taipei, the Transport Minister sought the advice of a feng shui master who divined that the main station had bad feng shui, including a faulty bagua symbol on its premises, and so the ministry realigned at considerable expense the station's south entrance (Bruun 2008, p.135).

It is increasingly common for architectural design and building construction in San Francisco, Los Angeles, Vancouver, Toronto, London, Sydney, Auckland and most major cities around the world to proceed in accordance with feng shui principles; and even in accordance with neo- or quasi-feng shui principles.

The Origin and Elaboration of Feng Shui
The ancient cosmological fount of feng shui was codified during the Bronze Age (10th-4th centuries bce) in the Confucian classic The I Ching or Book of Changes (Rutt 1996). One historian said of this work that it is:
the mother of Chinese divination, having fostered both its diversity and persistence; … feng shui is anchored in its perception of reality … it stands out as the single most important book in Chinese civilization … comparable to the sacred scriptures of the other great civilizations (Bruun 2008, pp.100-101).
Since the beginning, feng shui has been intimately associated with geomancy, one of numerous systematic forms of divination that have a long history in Asia (March 1968, Smith 1991), but also elsewhere.

Two Historical Encounters between Feng Shui and the Western Scientific Worldview
It is informative to examine two moments in the history of contact between feng shui and Western science and philosophy. These historical episodes are illustrative of the general arguments advanced in this talk and can also serve as suitable 'hooks' for classroom discussion. In particular, there are lessons to be learnt from the celebrated engagements of two Christian missionaries with feng shui. First, the Jesuit priest Matteo Ricci in the late-16thcentury;second,theLutheranpastorErnstEitelinthemid-19thcentury. Both episodes have historical, philosophical, political, cultural, theological and scientific dimensions. The episodes can, to whatever degree is appropriate in the classroom and curriculum circumstance, be elaborated with science classes. They also provide ideal cases for cross-disciplinary cooperation among teachers.

Matteo Ricci

Matteo Ricci (1552-1610) was one of the first Europeans to give an informed and detailed appraisal of feng shui belief and practice in China, and certainly one of the first whose account gained wide readership. He was among the earliest, and foremost, of the Jesuit missionaries who were sent to Ming-dynasty China in the late 16thcentury following the thwarted efforts of Francis Xavier.

Ricci's mathematical, astronomical and chronological knowledge was taken up in a purely utilitarian way by the Chinese court and mandarins; it was seen to improve astronomy, astrology and calendar calculations upon which so much of the functioning of the Emperor's state apparatus depended. Ricci's 'natural philosophy', or his Western science, had minimal impact on Chinese science and no impact on Chinese culture.

Chapter Nine of Book One of the Journal is titled 'Concerning Certain Rites, Superstitious and Otherwise'. He then proceeds by noting:

No superstition is so common to the entire kingdom as that which pertains to the observance of certain days and hours as being good or bad, lucky or unlucky, in which to act or to refrain from acting, because the result of everything they do is supposed to depend upon a measurement of time. … These almanacs are sold in such great quantities that every house has a supply of them … and in them one finds directions as to what should be done and what should be left undone for each particular day, and what precise time each and everything should be done. In this manner the entire year is carefully mapped out in exact detail. (Ricci 1615/1953, pp.82-83)

Ricci elaborated on divination:

These people worry a great deal about judging their whole lives and fortunes as dependent upon the exact moment of birth, and so everyone makes an inquiry as to that precise moment and takes an accurate note of it. Masters of this kind of fortune-telling are numerous everywhere … (Ricci 1615/1953, p.83) And he observes, not unexpectedly, that:
Fraud is so common and new methods of deceiving are of such daily occurrence that a simple and credulous people are easily led into error. These soothsayers frequently have confederates in a gathering who declare to a crowd that everything that was told to them by the performer came to pass just as he had predicted it. …. (Ricci 1615/1953,

pp.83-84)
Geomancy was thoroughly embedded in Ming dynasty (1368-1644) life, the practice being codified in the 1445 Daoist Canon that contained entire sections of geomantic charts for divination purpose. Few civil and military decisions were made without geomantic input; by law, no official building construction could commence without geomantic certification. Ricci regarded all of this as a superstitio absurdissima observing that:

What could be more absurd than their imagining that the safety of a family, honors, and their entire existence must depend upon such trifles as a door being opened from one side or another, as rain falling into a courtyard from the right or from the left, a window opened here or there, or one roof being higher than another? (Ricci 1615/1953)

Ernst Johann Eitel

Two hundred and fifty years after Matteo Ricci's another missionary, Sinologist and linguist covered the same ground. This was Ernst Johann Eitel (1838-1908), a German Lutheran missionary with a doctoral degree from the University of Tübingen, who lived for many years in Hong Kong, who travelled within China, who oversaw educational enterprises in Hong Kong, who published a history of the colony (Eitel 1895/1983), and who published translation dictionaries and studies of Buddhism (Eitel 1873). Importantly he published a substantial appraisal of the history, metaphysics and functioning of feng shui – Feng Shui: The Rudiments of Natural Science in China (Eitel 1873/1987). Feng Shui as a 'Black Art'

Eitel notes how the European construction in the Treaty Ports that followed the mid-nineteenth century Opium Wars, was constantly embroiled in feng shui disputes about the work's expected positive and negative impacts on the flow and distribution of chi in the port area. He observes how much of the foreigners' building work in Hong Kong inadvertently turned out to be in 'good' feng shui sites (access to water, protection from high wind, away from malaria swamps, and so on) which led many Chinese to impute advanced feng shui knowledge to foreigners.

No one needs cosmology and metaphysics to come to this conclusion. Water is beneficial in all ways: for drinking, plant growth, temperature control, transport, and so on. Good ecological and common-sense reasons suggest proximity to water and avoidance of wind tunnels make for good living places. People claiming this conclusion as warrant for feng shui (FS) belief are committing the elementary logical mistake of affirming the consequent:

FS → site A will be healthy and beneficial
Site A is healthy and beneficial
∴ FS is proved/warranted/confirmed

But, of course, any number of other 'theories', including scientifically informed ones, can equally suggest site A.
Quite predictably, two researchers report how feng shui-informed and feng shui-uninformed architects come to the same conclusion about the suitability of building sites, and even floor plans:

An empirical survey was conducted with architects in Sydney and Hong Kong, and the results show that the selection of surrounding environment for a building and interior layout as proposed by the [non-feng shui] architects generally concurs with the ideal Feng Shui model established more than two thousand years ago. (Mak & Ng 2005, p.427)

Eitel recognised that feng shui site selection and medical guidance goes beyond harmless and benign commonsensical practices:
Well, if Feng-shui were no more than what our common sense and natural instincts teach us, Chinese Feng-shui would be no such puzzle to us. But the fact is, the Chinese have made Feng-shui a black art, and those that are proficient in this art and derive their livelihood from it, find it to their advantage to make the same mystery of it, with which European alchemists and astrologers used to surround their vagaries. (Eitel 1873/1987, p.1)

Eitel here articulates a standard criticism: what is good in feng shui practice is merely dressed-up commonsense – build and plant in proximity to water and not in a wind tunnel or on a mountain top; have living areas orientated to the sun, and sleeping areas away from the sun; avoid having front and rear doors opening in an uninterrupted line; do not have toilets opening into living areas; etc.

The argument of this paper is that all the associated metaphysics, cosmology and ultimately worldview is just hand-waving. As the saying is: 'With the cosmology and two dollars you can ride the subway'. But it is not idle or harmless hand waving, as it opens the cultural door to mystification and worse still, to manipulation by charlatans. If people get accustomed to believing the fantastic, evidence-free, or evidence-neutral, chi narrative, then what other evidence-free or neutral beliefs might they be prepared to accept? European history if full of episodes of mass hysteria sustained by such gullibility.

Chinese Proto-Science and Avoidance of Experiment

Eitel sees feng shui as Chinese natural science, but for him it was a science that did not 'grow up' (Eitel 1873/1987, p.3). Eitel marks down Confucius and his influential early disciples for not engaging with and correcting the proto feng-shui systems of his age. Many historians and commentators on Confucianism make the same point: Confucius was not engaged by or interested in how the world worked; he had little if any concern with 'natural philosophy' (Chan 1957).

Fifty years after Eitel, Joseph Needham, and many others, debated why Chinese proto-science did not mature in the way that European seventeenth-century did. Needham, with his explicit Marxist convictions, looked to 'external' social factors for an answer (Needham 1963).
Eitel had better instincts on this central question of: Why was there no scientific revolution in China? His answer was the lack of an experimental tradition in China. Not 'kitchen' or pragmatic experiments dealing with how to improve production, transport, weapons, cuisine, or manufacturing, but mathematically formulated and controlled scientific experiments with explicit methodological principles. Towards the end of his book, he writes:
There is one great defect in Feng-shui, which our Western physicists have happily long ago discarded. This is the neglect of an experimental but at the same time critical survey of nature in all its details. (Eitel 1873/1987, p.69)

Eitel here echoes Kant's famous pronouncement in his Critique about the New Science only beginning when Galileo rolled balls down inclined planes and forced Nature to answer to questions that the natural philosopher asked: it was then that 'a light broke upon all students of nature' (Kant 1787/1933, p.20). Eitel might well have learnt from Kant's commentary during his own doctoral studies at the University of Tübingen. His observation was not far off the mark.

Appraising Eitel's important claim about the centrality of experiment is an occasion not just for historical study, but for scientific/philosophical analysis of what constitutes an experiment. This latter question has been widely and energetically addressed in recent philosophy of science literature.

Eitel's Appraisal of Feng Shui and the Educational Task in China

Eitel concludes his exposition by writing that while two thousand years ago the embrace of some of the fundamental ideas of feng shui was understandable and 'rational', but such embrace no longer is. He writes that feng shui exponents:
had studied nature, in a pious and reverential yet in a very superficial and grossly superstitious manner, but which, trusting in the force of a few logical formulae and mystic diagrams, endeavoured to solve all the problems of nature and to explain everything in heaven above and on the earth below with some mathematical categories. The result, of course, is a farrago of nonsense and childish absurdities. (Eitel 1873/1987, p.69)
Eitel had no hesitation in pointing to the educational project, specifically the science-education project, that was needed in his day:

The only powerful agent likely to overthrow the almost universal reign of Feng-shui in China I conceive to be the spread of sound views of natural science, the distribution of useful knowledge in China. ... let correct views be spread regarding those continually interchanging forces of nature, heat, electricity, magnetism, chemical affinity and motion; let these views be set forth in as forcible and attractive, but popular a form as Choo-he employed, and the issue of the

whole cannot be doubtful. (Eitel 1873/1987, p.69)
Although a Lutheran clergyman, he spoke with a voice informed by science and the Enlightenment:

The fires of science will purge away the geomantic dross, but only that the truth may shine forth in its golden glory. (Eitel 1873/1987, p.69)

Feng Shui, Education and Modernization of Chinese Culture

In the seventeenth century, China's adoption of Matteo Ricci's European technology, astronomy and mathematics left Confucianism untouched; so too it left the entire Chinese political or imperial system untouched, indeed the latter was strengthened. At the beginning of the twentieth century, a small minority of scholars strove for more radical rapprochement between Chinese culture and modern science. For example, Ch'en Tu-hsiu [Chen Duxiu] (1879-1942) was an ardent 'public intellectual', political reformist and opponent of obscurantist Confucian philosophy. He was one of thousands who looked to Western thought, especially science, in order to modernise Chinese thinking, and strengthen the society so that the endless humiliations of the late nineteenth and early twentieth centuries visited upon China by the European powers and Japan would not recur.

After living in France and absorbing a good deal of the thinking of the Enlightenment philosophes, Ch'en returned in 1910 to China and began the 'New Thought movement 'with its own journal New Youth. This was edited by Ch'en, and in it he published his own essay 'The French People and Modern Civilization'.
The first issue of New Youth contained an editorial essay 'My Solemn Plea to Youth' in which Ch'en wrote:

Our men of learning do not understand science; thus they make use of yin-yang signs and beliefs in the five elements to confuse the world and delude the people and engage in speculations on geomancy ... The height of their wondrous illusions is the theory of ch'I [primal force] ...We will never comprehend this ch'I even if we were to search everywhere in the universe. All of these fanciful notions and irrational beliefs can be corrected at their roots by science, because to explain truth by science we must prove everything with fact. Although this is slower than imagination and arbitrary judgment, every progressive step is taken on firm ground. It is different from those flights of fancy which in the end cannot advance one bit. (New Youth, 1915, vol.1, p.1. In Kwok 1965, p.65)

The editorial touches on most of the core scientific, philosophical, cultural and educational issues surrounding feng shui and how it is best treated in a school system. These were momentous issues for China at the beginning of the 20thcentury. The same issues recur in all societies and cultures as they 'come to terms with' science, and with Enlightenment beliefs especially secularism, liberalism and democracy in politics.
Clearly this task of 'cultural self-consciousness', as outlined by Chen, Tang and so many others, is an educational project that requires science-informed historical and philosophical input. It is a task with which all societies need to engage. Western and Middle-Eastern societies are as much in need of this historical consciousness as Asian societies.
The beginnings should be engendered by formal education; responsible science education will contribute to this task in all countries. The more explicitly the HPS dimensions of science are presented in classrooms, then the more fruitful will be such contribution to cultural self-consciousness. Perhaps above all other things, what HPS-informed science education can contribute to this permanent cultural task is an appreciation of the historical and philosophical connections between modern science and the Enlightenment tradition.

Teaching About Energy and Appraising Feng Shui

One obvious and non-controversial way to raise issues about feng shui in science classes is to do so when teaching units on energy. Throughout the world at all educational levels – elementary, secondary and college – energy is a ubiquitous topic in science programmes simply because energy is ubiquitous in nature. The study of Energy is one of the core requirements in the English school science programme where students are expected to detail different sources of energy and know how different cultures utilize these sources. Energy is one of the core 'cross cutting concepts' in the USA Next Generation Science Standards (NRC 2013).

In the USA, the Department of Energy (DoE) produced an educational guide that specifies an 'energy literate' person has:
An understanding of the nature and role of energy in the universe and in our lives. Energy literacy is also the ability to apply this understanding to answer questions and solve problems. (DoE 2012, p.4)

The US Department further elaborates that such a person 'Can assess the credibility of information about energy'.

Testable Claims about Chi Energy

Given the centrality of 'energy' in feng shui discourse and practice, and given the wide influence and impact of feng shui in Asian and now Western culture, these DoE objectives can assuredly be advanced by explicit treatment of feng shui in science classes. The DoE guide implies that students should be able to assess the credibility of feng shui energy claims (and indeed any other energy-related claims). If daily feng shui forecasts are on the nightly news, then asking a class to assess their credibility is hardly an outside imposition on the class.
Pleasingly there seem to be some opportunities for clear-cut scientific tests for the putative powers of chi. Dr. Yan Xin, a medical researcher from the Chinese Chi Research Centre, who has worked in major Western and Chinese universities, commendably spells out the power of chi in a testable manner (Yan 2015). As Karl Popper would say, he commendably puts his theory's neck on the experimental block:
the mind power or Qi emitted by a trained Qigong master can influence or change the molecular structure of many test samples, including those of DNA and RNA, even if these test samples are 6 to 2,000 kilometers away from the master. Qi can also effect the half-life of radioactive isotopes and the polarization plane of a beam of light as emitted from a Helium-Neon laser.

At first, and even last, reading these are stunning claims; they certainly have the patina of science. As Yan Xin's followers maintain: 'His discoveries are changing the way modern science is viewed, and challenging many of its assumptions' (ibid). But Dr Xin then retreats and takes the theory's head off the block:
Currently, the essential qualities of qigong and qi are difficult to study in a detailed, qualitative, and quantitative manner. (ibid)

Pleasingly serious scientific research journals require studies to be done in a 'detailed, qualitative, and quantitative' manner and so set a high bar for publication. Thus far, it seems, that feng shui 'research' has not met the standards of any reputable scientific journal. But gullible people, with minimal science literacy, read such claims and believe that modern science has so changed and has endorsed such nonsense.
But modern science is simply incompatible with the truth of these claims; they could never find outlet in any serious science research journal.

Another colleague, Dr Hui Lin, also of the Chinese Chi Research Centre offers the following striking example of chi power:
Consider a simple experiment on qigong potential. In this experiment people used their qi to shake pills out of a sealed bottle. However, the intermediate process was undetectable by any available means. The pills passed through the bottle (analogous to conducted experiments in which a person passes through a solid wall), even though the bottle is completely sealed and intact, without any possibility of tampering.

Accepting at face value the results, he concludes that:
This demonstrates the probable existence of a form of energy associated with qi which transcends the three or four [gravitational, electromagnetic, strong and weak interaction] fundamental forces.

This all sounds very scientific and certainly would cause a revision in our understanding of science and of the world picture that science has given us. But in Hui Lin's 'experiment', no independent witness to such 'transportation' is noted; and no replication study is reported. Independent observation and replication should be the beginning of any effort to bring these truly remarkable results into the scientific fold. They should be among the first things that an scientifically literate student or adult asks of

the remarkable experiment. Their absence is a powerful indicator of the whole feng shui practice being pseudoscientific.

Feng Shui as Pseudoscience

Belief systems, and associated practices, can usefully be categorized as: Science (mature and proto-science), Pseudoscience and Non-science. Such classification does depend upon adequate demarcation criteria, but these do not require any timeless essentialism. Membership of a category is a matter of family resemblance; there are clusters of criteria that mark out the categories, these can change over time, and not all boxes need be ticked,

Carl Hempel (1905-1997) usefully offered not so much a singular demarcation criterion, but rather a list of seven desiderata that identified good science, or specifically good scientific theories, among which are:

A theory should yield precise, preferably quantitative, predictions.
It should be accurate in the sense that testable consequences derivable form it should be in good agreement with the results of experimental tests.
It should be consistent both internally and with currently accepted theories in neighboring fields.
It should have broad scope.
It should predict phenomena that are novel in the sense of not having been known, or taken into account, when the theory was formulated.
It should be simple.
It should be fruitful. (Hempel 1983, pp.87-88; author formatting added)

It is unfortunate that Hempel conflates 'science' with 'theories'. Good theories, as Hempel characterizes them, are the expected outcome and indicator of good science; but science as an organized, structured, historical-sociological entity, needs further characterization beyond what suffices for good theory. Extra ontological, methodological and sociological criteria are required; the more so in order to separate science from pseudoscience. For a group to be called a scientific group or for it to be involved in scientific practice, it needs have the following characteristics:

It should reliably produce a 'quota' of good scientific theories as characterized above.
It needs to seek new knowledge, to do research; not be ossified, stand still and repeat extant knowledge.
It should be constituted as a research community pursuing cognitive goals and committed to finding out new things about the natural and/or social worlds; not just sharing beliefs, inquiring into texts.
Its members need be trained or certified in such cognitive inquiry; science can be advanced by lay-people, but if no or few members of the community are suitably trained, then the community falls short of being a scientific community;
It should appeal only to ontologically stable entities in its explanations and theorizing. reference to 'here today, gone tomorrow' entities, or entities that come in and out of existence depending on who is thinking about them, diminish the scientific status of theories and communities that propose them.
It needs be committed to at least pragmatic methodological naturalism as the basis for evidence collection and theory appraisal.

Methodological naturalism, in the final criterion, is not methodological materialism. The latter characterized the Mechanical Worldview of the seventeenth and eighteenth centuries (Schofield 1970), but with the progress of nineteenth and twentieth century science, where there was recourse to stable, yet non-material, explanatory and causal entities (non-contact forces, fields, radiation, gravitational waves, etc.) materialist ontology became a hindrance rather than an asset for science; and such novel entities became 'naturalised'.

It helps the argument of this paper to focus on just the first distinction, namely Science-Pseudoscience rather than the wider task of separating both from Non-sciences such as Art, History, Mathematics, Theology and so on. Whether these have justifiable warrants for their claims is a matter for separate investigation. Different philosophical, sociological and political indicators or markers of pseudoscience have been advanced.

Sven Hansson, a Swedish philosopher, provided one such list whereby a corpus of belief and practice can be judged pseudoscientific in as much as:

There is overdependence on authority figures.
Unrepeatable experiments are too frequently adduced.
Data selectivity, or cherry-picking of evidence is too common.
There is an unwillingness to seriously test claims and predictions.
Confirmation bias is endemic and disconfirmation is neither sought nor recognized.
Some explanations are changed without systematic consideration. (Hansson 2009)

And when:

They make claims about events and mechanisms in the natural world.
The claims cannot be epistemically warranted, yet effort is made to show their scientificity.
They too easily resort to auxiliary hypotheses to insulate claims from empirical refutation. (Hansson 2009)

A further characteristic that can be added to this list, is:

The practice makes scientific claims, but refuses to engage with the scientific community (publishing in research journals,

presenting at research conferences), whose status it is claiming.

Conclusion

Feng shui theorists and consultants are practicing something that superficially appears like science and is infused with scientific terminology - witness the title of the recent book Scientific Feng Shui for the Built Environment (Mak & So 2015) – but it is not science. The key content and methodological elements of science are missing:

There is no tradition of controlled and reproducible experiment.
There is no recognition of the problematic recourse to ad hoc rescuing of failed hypotheses.
There is a dramatic inconsistency with the core of established scientific knowledge, most especially the conservation of energy postulate.
There is no participation in the established, peer-reviewed, scientific research community and its journals.
There is altogether unwarranted dependence upon individual or sectarian interpretation of basic feng shui principles; there are hundreds of different feng shui 'schools' each with masters but no unified canon.
Finally there is a radical disjunct between the law-governed, deterministic worldview of science and the chaotic, idiosyncratic 'fortune-telling', 'auspicious times' worldview of feng shui. The latter is only imaginable if the fundamental laws of causation for macro objects are jettisoned; and if that happens then science is also abandoned.

All institutions, belief systems and ideologies benefit from historical study; from understanding themselves in an historical sequence and context. All the major religions have gained from developing such perspectives. Feng shui can benefit from the same historical analysis and this can be part of its examination in science classes. Across the spectrum of features of science - experimentation, authority, prediction, precision, mathematisation, idealisation, coherence (Matthews 2011) – feng shui can be juxtaposed with science, and similarities and differences drawn out. This is a way for students to learn about the nature of science. It will be apparent that feng shui violates all constitutive and procedural components of science. Such learning will deepen an understanding of the Nature of Science and will be a contribution of science education to the cultural health of society. With better organised curricula, perhaps history, social studies, philosophy and cultural studies departments can cooperatively contribute to the examination.

[References]

Bruun, O.: 2008, An Introduction to Feng Shui, Cambridge University Press, Cambridge.

Dainian, F. & Cohen, R.S. (eds.): 1996, Chinese Studies in the History and Philosophy of Science and Technology, Kluwer Academic Publishers, Dordrecht.

Department of Energy USA (DoE): 2012, Energy Literacy: Essential Principles an Fundamental Concepts for Energy Education, US Department of Energy, Washington, DC.

Eitel, E.J.: 1873, Buddhism: Its Historical, Theoretical and

Popular Aspects, Trübner & Co., London.
Eitel, E.J.: 1873/1987. Feng Shui: The Rudiments of Natural Science in China, Lane, Crawford & Co., Hong Kong, (Graham Brash, Singapore).
Eitel, E.J.: 1895/1983, Europe in China: A History of Hong Kong, (ed. H.J. Lethbridge) Hong Kong, Oxford University Press.
Guo, P.: 2001, The Zangshu, or Book of Burial, Stephen Field (trans.), web source. [original ≈ 300bce]
Hansson, S.O.: 2009, 'Cutting the Gordian Knot of Demarcation', International Studies in the Philosophy of Science, 23, 237-43.
Hansson, S.O.: 2013, 'Defining Pseudoscience and Science'. In M. Pigliccci & M. Boudry (eds.) Philosophy of Pseudoscience: Reconsidering the Demarcation Problem, University of Chicago Press, Chicago, pp.61-77.
Hempel, C.G.: 1983, 'Valuation and Objectivity in Science'. In R.S. Cohen & L. Laudan (eds.) Physics, Philosophy and Psychoanalysis: Essays in Honor of Adolf Grünbaum, Reidel, Dordrecht, pp.111-127.
Kant, I.: 1787/1933, Critique of Pure Reason, 2nd edit., N.K. Smith (trans.), Macmillan, London. (First edition, 1781).
Kwok, D.W.Y.: 1965, Scientism in Chinese Thought: 1900-1950, Yale University Press, New Haven, CT.
Mak, M.Y. & Ng, S.T.: 2005, 'The art and science of Feng Shui —a study on architects' perception', Building and Environment 40(3), 427-434.
Mak, M.Y. & So, A.T.: 2015, Scientific Feng Shui for the Built Environment: Theories and Applications, City University of Hong Kong Press, Hong Kong.
March, A.L.: 1968, 'An Appreciation of Chinese Geomancy', Journal of Asian Studies 27(2), 253-267.
Matthews, M.R.: 2011, 'From Nature of Science (NOS) to Features of Science (FOS)'. In M. S. Khine (ed.) Advances in the Nature of Science Research: Concepts and Methodologies, Springer, Dordrecht, pp.1-26.
Miller, J.D.: 2004, 'Public understanding of, and attitudes toward, scientific research: What we know and what we need to know', Public Understanding of Science 13, 273-294.
National Research Council (NRC): 2013, Next Generation Science Standards, National Academies Press, Washington DC.
Needham, J.: 1963, 'Poverties and Triumphs of the Chinese Scientific Tradition'. In A.C. Crombie Scientific Change: Historical Studies in the Intellectual, Social and Technical Conditions for Scientific Discovery and Technical Invention, from Antiquity to the Present, Basic Books, New York, pp.117-153
Ricci, M.: 1617/1953 On the Christian Mission among the Chinese. In L.L. Gallagher (1953), China in the Sixteenth Century: The Journals of Matthew Ricci, 1583-1610, Random House, New York.
Rutt, R.: 1996, The Book of Changes (Zhouyi): A Bronze Age Document, Curzon Press, Richmond.
Schofield, R.E.: 1970, Mechanism and Materialism: British Natural Philosophy in an Age of Reason, Princeton University Press, Princeton.
Smith, R.J.: 1991, Fortune-tellers and Philosophers. Divination in Chinese Society, Westview Press, Boulder CO.
Tobin, K.: 2000, 'Constructivism in Science Education: Moving On'. In D.C. Phillips (ed.) Constructivism in Education', National Society for the Study of Education, Chicago, pp.227-253.
Tobin, K.: 2015, 'Connecting science education to a world in crisis', Asia-Pacific Science Education, 1:2, (doi:10.1186/s41029-015-0003-z)
Yan Xin: 2015, Secrets and Benefits of Internal Qigong Cultivation, Amber Leaf Press.
Yoon, H.-K.: 2006, The Culture of Fengshui in Korea: An Exploration of East Asian Geomancy, Rowan & Littlefield, Plymouth, UK.
Zhang, Dainian: 2002, Key Concepts in Chinese Philosophy, (translated and edited by Edmund Ryden), Foreign Languages Press, Beijing.

KEYNOTE

▪ Keynote Speech 1 11:00-12:00 / Dec. 16, 2016 / Conference Hall

Genetic determinism in the genetics curriculum: An experimental test of the effects of Mendelian and Weldonian emphases

Radick, Gregory, University of Leeds, UK

✉G.M.Radick@leeds.ac.uk

Abstract

Twenty-first century biology rejects genetic determinism, yet an exaggerated view of the power of genes in the making of bodies and minds remains a problem. What accounts for such tenacity? This lecture will report an experimental study suggesting that the common reliance on Mendelian examples and concepts at the start of teaching in basic genetics is an eliminable source of determinism. Undergraduate students who attended a standard 'Mendelian approach' university course in introductory genetics on average showed no change in their determinism about genes. By contrast, students who attended an alternative course which, inspired by the work of a critic of early Mendelism, W. F. R. Weldon (1860-1906), replaced an emphasis on Mendel's peas with an emphasis on developmental contexts and their role in bringing about phenotypic variability, showed reduced levels of determinism. Improvements in both the new Weldonian curriculum and the study design are in view for the future.

"Battling the undead": that is how the philosopher Philip Kitcher memorably characterized the fight against genetic determinism (Kitcher 2001). It should have expired long ago, and yet, in small ways and larger, in the public as well as backstage cultures of science and medicine, it remains not just resilient but resistant to challenge (see, e.g., Moore 2008).

I want in my lecture to end or see an increasingly well-confirmed diagnosis of the nature of the problem faced and also propose a new form of therapy. In brief, the diagnostic hypothesis that my co-author Annie Jamieson and I propose is that the Mendelian emphases typical of introductory genetics teaching at every level promote determinist attitudes which persist long after people learn that, in fact, genes are not destiny. The therapy that we recommend, on the basis of an experimental trial that we conducted at the University of Leeds in the autumn of 2013, is a course of introductory genetics that emphasizes not Mendelian patterns and principles but developmental contexts and phenotypic variability as the upshot of those contexts. The rest of this precis introduces the historical source of our own perspective on Mendelism and determinism: the largely neglected writings of early Mendelism's most profound critic, W. F. R. Weldon.

In the lecture itself, I'll go on to describe the experimental trial, which, along with the delivery of the new Weldonian curriculum, involved the gathering of "before and after" data on genetic determinism in two groups of undergraduate students: those taking the Weldonian course; and those taking the standard, start-with-Mendel introductory genetics course. I'll then report and analyse the gathered data, quantitative and qualitative, with particular attention to our main finding: that where students on the Mendelian course on average showed no change in their determinism about genes, students on the Weldonian course showed a reduction in genetic determinism. I'll conclude with some reflections on this finding and on next steps to improve both the design of the experiment and the Weldonian curriculum at its heart.

The Weldonian Perspective

There are more ways than one for a genetics curriculum to be "non-Mendelian." Not all of the possible options - imagine, say, a Lamarckian curriculum - are scientifically respectable in the twenty-first century. Among the scientifically respectable options, not all are concerned primarily with combatting genetic determinism. An excellent, up-and-running example is Rosie Redfield's "Useful Genetics" MOOC. It grew out of her frustration with genetics teaching materials that, for all their patched-in updatings, appeared to be hopeless at producing students who actually understood genetics (as distinct from being able to pass exams in it). She thus decided to start afresh, stripping out Mendelism along with many other canonical topics in favour of molecular genetics and, as she put it in a manifesto, "what [students] will need in their daily lives - a solid understanding of how genes influence phenotypes, of natural genetic variation, and of the mechanism of heredity" (Redfield 2012, 4).

By contrast, the non-Mendelian curriculum in the Leeds experiment, while also aiming to give students a "useful genetics" introduction, did so by stressing that lots of things, not just genes, influence phenotypes; that natural phenotypic variation is wide and worth taking at least as seriously as natural genetic variation; and that the "mechanism of heredity" is a developmental process, such that every inherited trait depends to some extent on interactions between the "genes for" that trait and a developmental context, including other genes but also broader physiological and physico-chemical environments. Furthermore, where Redfield explicitly jettisoned what she called "the historical approach" (Redfield 2012, 2), the Leeds curriculum took the inspiration for its content directly from the history of genetics.

The English biologist Walter Frank Raphael Weldon was, from 1899 until his death in 1906 at the age of forty-six, the Linacre Professor of Comparative Anatomy at Oxford (Magnello 2004; Pearson 1906). Nowadays he is remembered chiefly for three things. He was a pioneer of the statistical description and analysis of natural populations, or "biometry," notable in particular for work demonstrating natural selection in the wild. He was, in the name of biometry, a leading opponent of the grander claims of the new "Mendelism" as it emerged rapidly from 1900, following the famous rediscovery of Mendel's pea-hybrids paper that spring. And, in his role as Mendelian critic, he was the first to point out that, examined statistically, Mendel's data fit his theory a little too well. What recent historical study of Weldon's unpublished correspondence and manuscripts has begun to establish are the deeper concerns underlying that critical stance. When, in 1902, Weldon published a photograph showing that pea cotyledons were not, as per Mendel, either "yellow" or "green", but everywhere on the spectrum between those two colours, he meant to underscore a link he perceived between the overly capacious descriptive categories that Mendelism encouraged and the Mendelian concept of dominance as something permanently associated with a particular hereditary character, whatever the context (Weldon 1902a & b; Jamieson & Radick 2013; Radick 2015). For Weldon, that concept looked, in the light of the recent progress of biology (and especially experimental embryology), wholly untenable. The same character could be dominant or not dominant depending on what was interacting with what. Of course, if, following Mendel's example, an investigator deliberately excludes "interfering" variation from a population under study - as Mendel did in purifying his breeding stocks - then the scope of those interactions will be much reduced. In a limited way, the resulting patterns can be illuminating, and Weldon thought Mendel's were. But what they show is not how inheritance really works - the mechanism of heredity - but how it works under highly unusual and, as far as natural populations go, entirely unrepresentative conditions.

Weldon's most sustained statement of this developmentalist, interactionist perspective on inheritance lies buried away in a manuscript entitled Theory of inheritance that he left unpublished and indeed uncompleted at his death in 1906. Extracts have recently appeared, and a scholarly edition is

now in preparation (Jamieson & Radick forth.). More immediately, the Weldonian curriculum in introductory genetics has been developed as a means of addressing the question of the nature and scale of the difference Weldon's perspective might have made to the subsequent history of genetics had Weldon lived and been successful in promoting his views. Suppose present-day biology textbooks were the descendants of a history where Weldon had won the argument, or more so than he actually did. What would those textbooks look like? And what would the students who learned from them be like? In particular, would they be less prone to genetic determinism than the students coming out of a Mendelian curriculum? (Back in the day, Mendelians were unabashed about that determinism. William Bateson, Weldon's counterpart on the Mendelian side, reflected later in life that "Scientific Calvinism" was not a bad shorthand for the Mendelian message (Bateson 1984,vi).)

Needless to say, as a matter of principle, no one should need Weldon's example in order to construct a curriculum along the variability-and-context-emphasizing lines of the Leeds experimental curriculum. A devoted reader of the collected works of Richard Lewontin (e.g., 1982, 1991; Rose, Kamin & Lewontin 1984) and Evelyn Fox Keller (e.g., 2000, 2010, 2014) would be well placed and well motivated to come up with more or less the same thing. Other routes to the same destination run through the small but scorching critical literatures on the defects of "dominance" talk (Allchin 2000, 2002, 2005; Falk 2001), "gene for" talk (Kitcher 1995, ch. 11; Burian & Kampourakis 2013), and overreliance on monogenic traits in genetics teaching (Dougherty 2009; Lewis 2011). There is even a growing international body of work exploring the links between persistent genetic determinism and persistently Mendelian ways of teaching, talking and thinking about genetics (see, e.g., Gericke & Hagberg 2007; Castéra, Bruguière & Clément 2008; Castéra et al. 2008; Gericke & Hagberg 2010a; Gericke & Hagberg 2010b; Dougherty 2010; Dougherty et al. 2011; Santos, Mariane & El-Hani 2012; Gericke, Hagberg & Jorde 2013; Gericke et al. 2014; Thörne & Gericke 2014; Smith & Gericke 2015; Aivelo & Uitto 2015). Yet in practice Weldon's example has been indispensable. Perhaps determinist Mendelism is so pervasively a part of what biology has become that the only way truly to escape its grip is to learn from thoughtful, well-informed people who were never in its grip in the first place - from, that is, contemporary critic-witnesses such as Weldon. (It is striking that Fox Keller's The century of the gene is volubly brilliant on why the old gene concepts and language must go yet silent on what should replace them.)

A related point is that, historically considered, the Weldonian perspective did not so much disappear from genetics as take up permanent residence on the conceptual sidelines, where it became a kind of intellectual mascot: a colourful tag-a-long, worth putting in the spotlight from time to time to liven up proceedings, and even accumulating its own, small, slightly oddball fan club, but ultimately inconsequential and, when paid too much attention, tiresome. Thus one reads early on in The mechanism of Mendelian heredity (1915), by T. H. Morgan and his students from the famous Columbia University fly room, that they take for granted as the essence of the Mendelian creed that "every character is the realized result of the reaction of hereditary factors with each other and with their environment" (Morgan et al. 1915, 46). No big deal: and once stated, it need never be revisited, through pages and pages on chromosomes, Mendelian factors, and patterns of inheritance in experimental lineages.

Those who did make a fuss down the decades are a most heterogeneous bunch. So we find Hermann Muller, the great theorist in the Morgan group, insisting in writings of the 1930s and 40s on the complexity of the relationship between genotype and phenotype, given genic interactions and environmental influences (Muller 1930, 1947). We find Lancelot Hobgen, longtime champion of the importance of the "nurture" side of nature-nurture controversies, calling in the 1960s for reform of genetics education in medicine founded on "the realization of the immensely complex possibilities of interaction between nature and nurture at every stage in a development process rightly conceived as embracing the whole life cycle" (Hogben 1963). And we find Sir Peter Medawar, in his sympathetic 1977 review of Leon Kamin's book on Cyril Burt and IQ in the New York Review of Books, explaining why the whole notion that a character can be partitioned into the inherited and the acquired is nonsense because, as the likes of Hogben and J.B.S. Haldane had made plain, "the contribution of nature is a function of nurture and of nurture a function of nature, the one varying in dependence with the other, so that a statement that might be true in one context of environment and upbringing would not necessarily be true in another." Superb teacher that he was, Medawar went on to give compelling examples. In humans, the genes behind an inability to digest phenylalanine obey Mendelian rules; but the mental retardation associated with them - and so the condition, phenylketonuria, that those genes are "for"— can be avoided by bringing up the affected child in a world free from phenylalanine, in which case the condition is at least as aptly described as environmental in origin. Or, he urged, consider eye colour in the brackish shrimp Gammarus chevreuxi. Some genetic combinations make eye colour appear to be wholly under environmental control; some ambient temperatures allow for patterns in colour inheritance conforming to Mendelian rules (Medawar 1977, 171–2).

Imagine what genetic knowledge would look like if interaction was the main message, and scenarios in which interaction can (for certain purposes) be ignored are relegated to the margins. That imagined reorganization - with flipped centre and periphery, foreground and background, grand generalization and special case - is the vision behind the curriculum taught in an experimental way in Leeds in autumn 2013. It is a "Weldonian" curriculum in that Weldon's work on inheritance is the inspiration, though, for reasons set out later, neither Weldon nor the debate that provoked him to undertake that work were included.

A couple of further terminological notes before we proceed to describe the experiment in detail. First, "genetic determinism" is a problematic term for a host of reasons, among them its historical origins as a term of abuse rather than self-description (cf. "social Darwinism," "racism" etc.). Here it refers to a stance or attitude towards genes as overriding "super causes" in the making of bodies and minds; or, looked at from the other direction, towards bodies and minds as in the main the product of the action of "genes for" bodily and mental constituents. Kostas Kampourakis' definition well captures our use of "genetic determinism": "genes invariably determine characters, so that the outcomes are just a little, or not at all, affected by changes in the environment or by the different environments in which individuals live." So construed, genetic determinism is a matter of degree, marked at one pole by default credulousness towards specific and general claims about the all-determining power of genes, and at the other pole by default scepticism towards such claims (such scepticism being, of course, not at all the same thing as default environmental determinism).

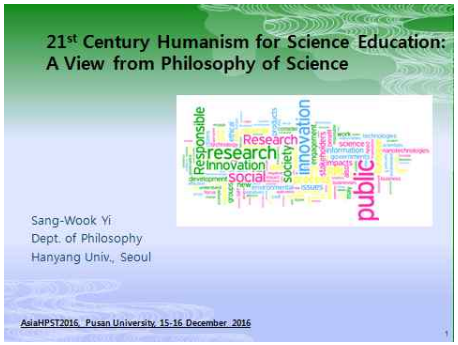
The hypothesis under investigation in the Leeds experiment is that the teaching of Mendel's experiments with hybrid peas - where visible traits are all-or-nothing, and everything depends on "genes for" those traits, and on nothing other than those genes - as foundational for understanding genetics is an eliminable source of support for the genetic-determinist attitude. In connection with genetic determinism we will also refer in what follows to "genetic optimism," by way of capturing the inference that people who believe that genes are a "super cause" are also likely to believe that increased understanding of genes, and greater ability to manipulate them, will be a "super solution," especially in relation to human health and medical developments.

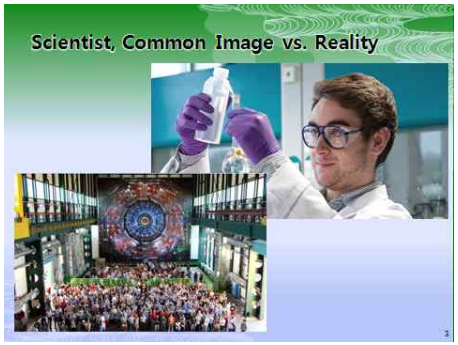
The other term needing comment is "interaction." In Kitcher's essay likening genetic determinism to the undead, he noted that "Lewontin's own response to the continued re-emergence of genetic determinism has been to deny the correctness of the interactionist credo, the conventional wisdom to which purveyors of determinist claims retreat in the face of criticism" (Kitcher 2001, 283–4). As Kitcher explains, that denial amounts to a repudiation of the idea that there are ever two differentiated entities, "genes" and "environment," which then go on to have "interactions." Rather, for Lewontin we ought, in dialectical-Marxist fashion, to liberate our thinking from all such reductive reifications and embrace the reality of process. Kitcher finds all of that needlessly obscure, in ways that jeopardize the larger cause of battling genetic determinism. Our own sympathies extend to both sides in this debate; but for present purposes, we are, like Kitcher, using "interaction" as a marker for a point of view that is not just an intellectually upmarket version of genetic determinism.

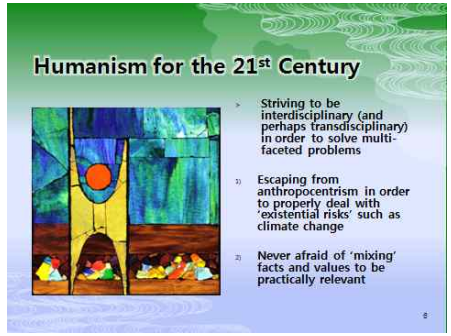
▪ Keynote Speech 2 13:30-14:30 / Dec. 16, 2016 / Conference Hall

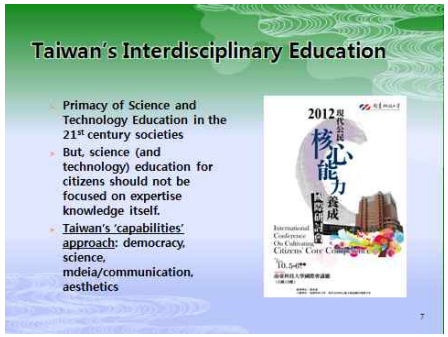
21st century humanism for science education: A view from philosophy of science

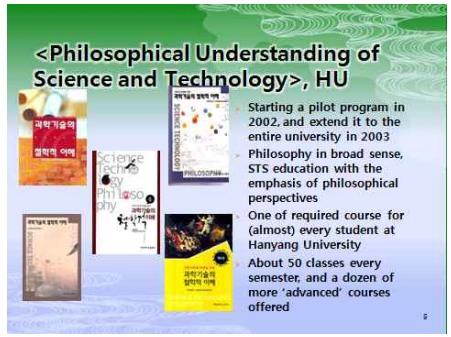
Lee, Sangwook, Hanyang University, Korea
✉dappled@gmail.com

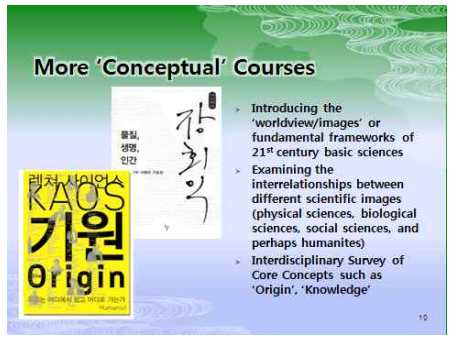


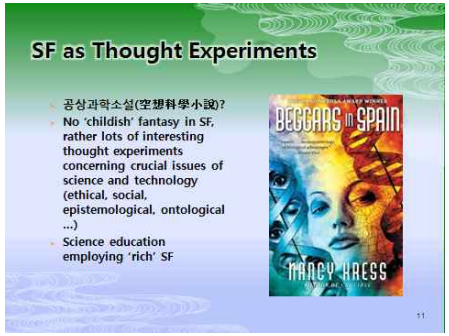












▪ Keynote Speech 3 11:00-12:00 / Dec. 17, 2016 / Conference Hall

The relevance of social epistemology for science education: A theoretical and historical case

Kuhn vs. Popper on criticism and dogmatism in science: A resolution at the group level

Rowbottom, Darrell, Lingnan University, Hong Kong
✉Darrellrowbottom@ln.edu.hk

[1)]Popper repeatedly emphasised the significance of a critical attitude, and a related critical method, for scientists. Kuhn, however, thought that unquestioning adherence to the theories of the day is proper; at least for 'normal scientists'. In short, the former thought that dominant theories should be attacked, whereas the latter thought that they should be developed and defended (for the vast majority of the time).

Both seem to have missed a trick, however, due to their apparent insistence that each individual scientist should fulfil similar functions (at any given point in time). The trick is to consider science at the group level; and doing so shows how puzzle solving and 'offensive' critical activity can simultaneously have a legitimate place in science. This analysis shifts the focus of the debate. The crucial question becomes 'How should the balance between functions be struck?'

1. Introduction - Criticism and the Growth of Knowledge

Criticism and the Growth of Knowledge was the flashpoint for a well-known debate between Kuhn and Popper, in which the former emphasised the importance of 'normal science' qua puzzle solving and the latter (and his supporters) questioned the very idea that 'normal science', so construed, could count as good science at all.

Kuhn's basic idea was that science would hardly get anywhere if scientists busied themselves with attacking what they already had, rather than accepting and refining it. But Popper instead emphasised the importance of striving to overthrow theories that might very well, for all their designers and users knew, be false (or otherwise unfit for purpose). The debate was inconclusive because both sides clearly had a perfectly reasonable point.

The natural solution would have been to take the middle ground - i.e. to suggest that scientists should feel free to attack or to uncritically accept - but both Popper and Kuhn appear to have avoided this option because they ultimately considered the matter, I will contend, only at the level of the individual scientist. By this, I mean that each thought about how one particular scientist ought to behave, and then extrapolated from this to determine how they thought a group of scientists should behave. And on the one hand, it is hard to see how it can be right for an individual (and by extrapolation every) scientist to blithely assume that what everyone else is doing is basically right, and that the theories she is given are fit for purpose. On the other, it is difficult to see how it could be right for a (and by extrapolation every) scientist to treat the canon of her science as fundamentally wrong, and to spend all her days objecting to the basic

1)Rowbottom, D. (2011). Kuhn vs. Popper on criticism and dogmatism in science: A resolution at the group level. *Studies in History and Philosophy of Science* 42(1), 117–124.

metaphysical principles underlying it.

In this paper I will explain how thinking at the level of the group, using a functionalist picture of science, provides a means by which to resolve the tension. I do not claim that this notion is entirely new - Hull (1988), Kitcher (1990) and Strevens (2003) all discuss the importance of the division of cognitive labour, although not with emphasis on attitudes - but I would venture to declare that the subsequent analysis is far more penetrating than that recently offered by Domondon (In Press) in this journal, and previously by Fuller (2003)[2]. In fact, it shows precisely how we can resolve, and move beyond, the kind of 'Kuhn vs. Popper' problems with which they are concerned. I shall begin by explaining the positions of Popper and Kuhn in greater depth.

2. Popper on Criticism

From the beginning of his career, Popper pushed the idea that a critical attitude is at the heart of the scientific persona, and that a critical method is its proper counterpart. Despite his well-known emphasis on the importance of falsifiability, he acknowledged in the original version of *The Logic of Scientific Discovery* (i.e. in 1934 but only translated into English in 1959) that:

A system such as classical mechanics may be 'scientific' to any degree you like; but those who uphold it dogmatically - believing, perhaps, that it is their business to defend such a successful system against criticism as long as it is not conclusively disproved - are adopting the very reverse of that critical attitude which in my view is the proper one for the scientist. (Popper 1959, p.50)

Just a little later, in an article in Mind, he declared:

[I]t is the most characteristic feature of the scientific method that scientists will do everything they can in order to criticize and test the theory in question. Criticizing and testing go hand in hand: the theory is criticized from very many different standpoints in order to bring out those points which may be vulnerable... (Popper 1940, p.404)

And throughout the rest of his career, at least until Criticism and the Growth of Knowledge appeared, Popper adhered to this line. In The Open Society and its Enemies, he wrote: '[R]ationalism is an attitude of readiness to listen to critical arguments and to learn from experience.' (Popper 1945, vol. II, p.249). In the preface to the first English edition of *The Logic of Scientific Discovery*, he wrote: 'I equate the rational attitude and the critical attitude. The point is that, whenever we propose a solution to a problem, we ought to try as hard as we can to overthrow our solution, rather than defend it.' (Popper 1959, p.16). Sure enough, the message is the same in *Conjectures and Refutations*: 'The critical attitude, the tradition of free discussion of theories with the aim of discovering their weak spots so that they may be improved upon, is the attitude of reasonableness, of rationality.' (Popper 1963, p.67) And even in more obscure places, e.g. in Popper's response to a critique of his views on demarcation by his ex-student W. W. Bartley, we find passages such as the following:

[W]hat characterizes the scientific approach is a highly critical attitude towards our theories rather than a formal criterion of refutability: only in the light of such a critical attitude and the corresponding critical methodological approach do 'refutable' theories retain their refutability. (Popper 1968, p.94)

The point behind all this textual evidence is not to belabour the point that Popper was pro-criticism. Rather it is supposed to throw the following passage, in *Criticism and the Growth of Knowledge*, into sharp relief:

I believe that science is essentially critical... But I have always stressed the need for some dogmatism: the dogmatic scientist has an important role to play. If we give in to criticism too easily, we shall never find out where the real power of our theories lies. (Popper 1970, p. 55)

What happened? Only at two other points before 1970, in Popper's published works, did he suggest that there is a need for dogmatism in science. One key passage is as follows:

[D]ogmatism allows us to approach a good theory in stages, by way of approximations: if we accept defeat too easily, we may prevent ourselves from finding that we were very nearly right. (Popper 1963, p.64)[3]

However, the extent to which dogmatism is useful, according to this view, is only in so far as we are fallible. That is to say, dogmatism will only prove useful on those occasions where we are 'very nearly right' despite evidence to the contrary. But how about when we are wrong? And furthermore, might we not accept a methodological rule such as 'Do not accept that a theory is falsified too easily' without being dogmatic at all? We will return to these questions when we have looked at what Kuhn had to say about dogmatism.

3. Kuhn on Dogmatism

In contradistinction to Popper, Kuhn suggested that adherence to the status quo was characteristic of actual 'normal', and derivatively good, science.[4] Infamously, Kuhn (1996,p.80) claimed that an experiment which back fires is normally taken, *and should normally be taken*, to reflect badly on the scientist that performs it: 'Failure to achieve a solution discredits only the scientist and not the theory ··· "It is a poor carpenter who blames his tools"...'

Moreover, Kuhn (ibid., p. 80) suggested that normal science can enable us 'to solve a puzzle for whose very existence the validity of the paradigm must be assumed'. So in short, he thought that work within a paradigm (qua disciplinary matrix) is possible only if that paradigm is taken for granted. Later in The Structure of Scientific Revolutions, he expressed this view at greater length:

[T]rial attempts [to solve puzzles], whether by the chess player or by the scientist, are trials only of themselves, not of the rules of the game. They are possible only so long as the paradigm itself is taken for granted. (Kuhn 1996, p. 144-145)

As I have argued elsewhere (Rowbottom 2006 and Rowbottom Forthcoming A), this is an elementary mistake. On the contrary, such puzzles 'exist' whether or not the paradigm is assumed to be valid, because we only need to consider what would be the case if the paradigm were valid in order to examine them. By way of analogy, we can consider whether p & q follows from p and q in classical logic without assuming that both p and q are true, or indeed assuming that classical logic is fit for purpose (whatever our stance on psychologism in the philosophy of logic happens to be).

Kuhn (1996, p. 24) used similarly strong language elsewhere:

By focusing attention upon a small range of relatively esoteric problems, the paradigm forces scientists to investigate some part of nature in a detail and depth that would otherwise be unimaginable...' [My emphasis]

However, we might interpret this a little more loosely by thinking about what is 'forced' in order to demonstrate one's proficiency in, and even to remain a recognised worker in, a discipline. In essence, Kuhn appears to have thought that scientists would not be motivated to tackle such esoteric problems (or puzzles) without rigid belief - or even faith - in the paradigm.

This claim may also be somewhat dubious, however, because it is possible to do things for extrinsic reasons. I could learn to recite a poem in order to impress a prospective lover without having any interest in verse or metre, just as a scientist could be content to solve puzzles, in the short term, in order to support himself and slowly build a reputation which would lead to some of his potentially revolutionary ideas being taken more seriously by his peers.

Nevertheless, Kuhn had a valid point to the extent that he was worried about scientists becoming hypercritical: 'The

2) Forgive me if this sounds immodest. My view may simply be a result of the gulf between the philosophy of science and science studies. No doubt the reader can reach a judgement as to the relative accuracy and depth of our respective treatments.

3) This passage is from a chapter based on a lecture delivered in 1953, but I do not know if it appeared in the original. (The other place is a footnote in Popper's revised version of 'What is Dialectic?', again in *Conjectures and Refutations*. In the original paper in *Mind* – Popper 1940 – the relevant footnote did not appear.) It would be interesting to see if this is an addition made after 1961, when Kuhn presented his paper on the function of dogma in Oxford (later published as Kuhn 1963). Gattei (2008, p.40) notes that Lakatos attended Kuhn's talk, and also that it caused somewhat of a stir. It is therefore safe to assume that Popper knew about it.

4) In fact, Kuhn (1970b, p.233) suggested that 'the descriptive and the normative are inextricably mixed'.

scientist who pauses to examine every anomaly he notes will seldom get significant work done.' (Kuhn 1996, p.82) And this, as we will see in the next section, is where Kuhn's objection to Popper's emphasis on criticism has some bite. If high confidence (even if not blind faith) in the paradigm qua disciplinary matrix did not put some areas 'off-limits' for legitimate criticism, then scientists would be stuck arguing over fundamentals.

4. Kuhn vs. Popper in Criticism and the Growth of Knowledge

The stage has now been set for an examination of the exchange between Popper and Kuhn in Criticism and the Growth of Knowledge. We have seen that the former emphasised the importance of criticism and non-conformity in science, whereas the latter thought that conformity and focused puzzle-solving are essential (at least in 'normal science'). It is therefore clear that they were set for a collision course when they were brought together, as Gattei (2008, ch.2) illustrates.[5)]

Perhaps we should start by noting that Popper agreed with Kuhn that 'normal science' exists. Unsurprisingly, however, he did not describe it in flattering terms:

"Normal" science, in Kuhn's sense, exists. It is the activity of the non-revolutionary, or more precisely, not-too-critical professional: of the science student who accepts the ruling dogma of the day; who does not wish to challenge it; and who accepts a new revolutionary theory only if almost everybody else is ready to accept it - if it becomes fashionable by a kind of bandwagon effect. (Popper 1970, p.52)

Popper (ibid.) continued by expressing pity for the predicament of 'normal scientists', with reference to educational norms: 'In my view the "normal" scientist, as Kuhn describes him, is a person one ought to be sorry for... He has been taught in a dogmatic spirit: he is a victim of indoctrination. He has learned a technique which can be applied without asking for the reason why (especially in quantum mechanics)...'

Kuhn disagreed with Popper not because he thought that criticism is unimportant for scientific progress (whatever that may consist in[6)]),but rather because he thought that it should only be occasional. (We can admit, of course, that puzzle-solving involves some criticism. The point is just that the scope of this is rather narrow.) Kuhn summarized his view as follows:

Sir Karl... and his group argue that the scientist should try at all times to be a critic and a proliferator of alternate theories. I urge the desirability of an alternate strategy which reserves such behaviour for special occasions... Even given a theory which permits normal science... scientists need not engage the puzzles it supplies. They could instead behave as practitioners of the proto-sciences must; they could, that is, seek potential weak spots, of which there are always large numbers, and endeavour to erect alternate theories around them. Most of my present critics believe they should do so. I disagree but exclusively on strategic grounds... (Kuhn 1970b, p. 243 & p. 246)

But what are the strategic grounds upon which Kuhn made his recommendation? His fundamental idea was that only by working positively with our current theories for a considerable period - trying to refine them, improve and increase their applicability, and so forth[7)] - can we discover their true strengths and weaknesses. And then if we do decide that change is needed, we will know where to focus our attention:

Because that exploration will ultimately isolate severe trouble spots, they [i.e. normal scientists] can be confident that the pursuit of normal science will inform them when and where they can most usefully become Popperian critics. (Ibid., p. 247)

One problem with Kuhn's suggestion is that he leaves it so vague. It is not clear, for instance, what counts as a severe trouble spot (and who should get to decide). Furthermore, it is unclear how long we should stick with a theory in the face of trouble spots. And finally, crucially, it is unclear why working with a theory for a long time should improve the chance of isolating genuine limitations of the theory. This is clearer when we consider Kuhn's proposed strategy in the light of Duhem's (1954, pp. 183-90) thesis - that 'an experiment ··· can never condemn an isolated hypothesis but only a whole theoretical group··· [so] a "crucial experiment" is impossible'.

In short, the salient question is "When should one challenge the theory itself, rather than the auxiliary assumptions used in order to derive predictions from it?" Kuhn seems to have suggested that the auxiliaries do (and should) always give way in 'normal science'[8)]. Naturally this is completely a todds with Popper's (1959, p.83) dictumthat: 'As regards auxiliary hypotheses··· only those are acceptable whose introduction does not diminish the degree of falsifiability or testability of the system in question.'

Clearly it would be foolish to recommend that we should always consider theories falsified when predictions derived from them, in combination with auxiliary hypotheses, are inconsistent with observations. So Kuhn's recommended strategy is certainly an improvement on naive falsificationism (which was never actually endorsed by Popper).

But let us now reconsider the passage highlighted in the earlier discussion of Popper's views on criticism:

[T]he dogmatic scientist has an important role to play. If we give in to criticism too easily, we shall never find out where the real power of our theories lies. (Popper 1970, p. 55)

We can now see that Popper might instead have said that we should be willing to criticise auxiliary hypotheses as well as theories, and that we shouldn't be too quick to condemn the latter rather than the former.[9)] But there is quite a difference between saying this and saying that 'the dogmatic scientist has an important role to play', because presumably it is possible to attack auxiliary hypotheses rather than theories, in the light of evidence that falsifies the conjunction there of, without being dogmatically committed to the theories. Therefore Popper did not intend 'dogmatism' in the same sense that Kuhn did, as he continued by pointing out:

[T]his kind of dogmatism is not what Kuhn wants. He believes in the domination of a ruling dogma over considerable periods; and he does not believe that the method of science is, normally, that of bold conjectures and criticism. (Ibid.)[10)]

Popper's comment here is fair, because Kuhn was much more extreme in his claims about the value of shielding theories from criticism. The following two quotations, in particular, illustrate this:

It is precisely the abandonment of critical discourse that marks the transition to a science. (Kuhn 1970a, p. 5)

Lifelong resistance, particularly from those whose productive careers have committed them to an older tradition···is not a

---

5) For example, Gattei (2008, p. 40) notes that the provisional programme for the Colloquium on which *Criticism and the Growth of Knowledge* was based: 'describes the session as follows:

July 13, Tuesday	*Criticism and the Growth of Knowledge I*
Chairman:	Sir Karl R. Popper
9:15–10	T.S. Kuhn: *Dogma versus Criticism*
10:15–11	P. Feyerabend: *Criticism versus Dogma*
11:15–12:45	Discussion'

He adds: 'Fundamental here are the contrasting words "criticism" and "dogma", chosen in order to emphasize the differences and characterize the two opposing positions – two diametrically opposed positions.' Gattei (2008, p.54) also defends the further claim that 'the critical reference of Kuhn's philosophy has always been Popper's falsificationism'.

6) Kuhn and Popper disagreed on the aim of science. However, this issue can be put to one side for present purposes. Kuhn and Popper disagreed on the aim of science. However, this issue can be put to one side for present purposes.

7) For more on the sorts of activity supposed to occur in 'normal science', see Kuhn 1996, ch. 3 and Rowbottom Forthcoming A.

8) Kuhn does not mention Duhem, or Duhem's problem, explicitly; rather, I propose that this is a helpful way to understand his view that 'anomalous experiences may not be identified with falsifying ones' (Kuhn 1996, p.146).

9) For more on how Duhem's thesis may be handled from a falsificationist perspective, by extending the notion of corroboration to auxiliary hypotheses, see Rowbottom Forthcoming B.

10) Writing of a similar earlier passage and anticipating some of this paper's later findings, Musgrave (1974, pp. 580–581) also notes that Popper's comments on dogmatism: '... might seem to conflict with his more frequent emphasis on the desirability of a critical attitude. The apparent conflict is heightened by the psychologicist terminology – to resolve it, we must read 'attitude' in a non-psychological way in both places. But then what is of 'considerable significance' is not a dogmatic attitude *as such*: a dogmatic attitude towards *T* will only be fruitful if it leads a scientist to improve *T*, to articulate and elaborate it so that it can deal with counterarguments; it will be unfruitful if it means merely that a scientist sticks to *T* without improving it.' I will later argue, however, that sometimes a dogmatic attitude may allow a scientist to do things that he otherwise would not.

violation of scientific standards (Kuhn 1996, p. 151)

It is not entirely misleading, therefore, to paint Popper and Kuhn as two extremists on the issue of the role of criticism in science. On the one hand, Popper suggested - at many points in his writing, at least - that:

(P) Each and every scientist should have a critical attitude (and follow the same critical procedures).

On the other, Kuhn - or at least a slight caricature of Kuhn[11]- suggested that:

(K) Each and every scientist should puzzle solve within the boundaries of the disciplinary matrix, on the basis of the exemplars therein, until almost every scientist comes to see particular failures as indicating serious anomalies.[12]

I should emphasise that (K) only goes for 'normal science', and that 'puzzle solving' involves many different forms of activity (as shown later in figure 5). It is crucial to the plausibility of Kuhn's view that 'rational' disagreement between scientists (Kuhn 1977, p.332) is permissible during periods of extraordinary science.

It appears to follow that it is necessary (and not merely sufficient) for the best possible science for each and every scientist to either (on P) be maximally critical, or (on K) be an expert puzzle solver (and/or to let critical activity have a narrow and well-defined scope for most of the time). So each and every scientist is expected to perform the same functions, qua scientist, on either view.[13] Failure to do so will lead to some thing less than ideal science.

In what follows, I shall challenge this notion that all scientists should adopt similar stances, and suggest that the best possible science may be realizable in more than one way. I will also suggest that there is a place for dogmatism in something close to Kuhn's sense when we look at matters at the group level, but also that critical procedures are crucial. The key idea, as Kitcher (1990, p. 6) puts it, is that there is 'a mismatch between the demands of individual rationality and those of collective (or community) rationality.'[14]

5. A Functional Analysis

The differences between Kuhn and Popper can be neatly understood by thinking in terms of functions, as I will show below. Moreover, thinking in this way suggests a means by which to resolve their debate; namely to consider functions at the group, rather than the individual, level.

11) I would defend the view that this is a fair interpretation of Kuhn's view in the first edition of *The Structure of Scientific Revolutions*. Several commentators on this paper have suggested it is a caricature of his later position; I disagree to the extent that I think he maintained that non-puzzle-solving functions are required only in extraordinary science.

12) Of course the *proper* mechanism by which scientists should come to see particular failures as indicating serious anomalies is never satisfactorily explained in Kuhn's work. And furthermore, it appears that one scientist or another will have to start a chain reaction by questioning the boundaries of the disciplinary matrix. But for present purposes, let us put this to one side.

13) This may be slightly unfair to Kuhn, because puzzle-solving involves a variety of activities. But Kuhn nowhere explained why some scientists might engage in one type of puzzle-solving, and others engage in another. Furthermore, he did not endeavour to say how (or even if) a balance ought to be struck. For more on this issue, see footnote 20 and the discussion of stances and paradigms in Rowbottom Forthcoming A.

14) Why did Kuhn and Popper not consider this possibility? It is perhaps easier to say for the latter, given his methodological individualism and the focus on proper scientific method for the individual of earlier philosophers of science, such as the logical positivists. In short, Popper strongly emphasised the importance of inquirers critically engaging with one another and the significance of tradition, but did not develop a theory of testimony (such as the one offered by Diller 2008) or of non-critical interaction in inquiry more generally. (In his favour, though, I should add that Popper (1975) noted 'that should individual scientists ever become "objective and rational" in the sense of "impartial and detached", then we should indeed find the revolutionary progress of science barred by an impenetrable obstacle'.) The former, on the other hand, was clearly in the correct intellectual territory to think about research groups in terms of inputs, outputs, and functions (or processes). Tentatively, I would suggest that his failure to move to a view of group rationality as distinct from individual rationality was as a result of what he saw in the history of science, from which he derived his normative conclusions, and what Watkins (1970, p. 34) calls his 'Paradigm-Monopoly thesis' that a 'scientist cannot, while under the sway of one paradigm, seriously entertain a rival paradigm'. Ultimately, Kuhn thought that sharp discontinuities (at the group level) are necessary for good science; but allowing for individual scientists to (rationally) do highly different things is to render such discontinuities unnecessary. Thus, Kuhn failed to entertain the notion that group functions and individual functions might come apart.

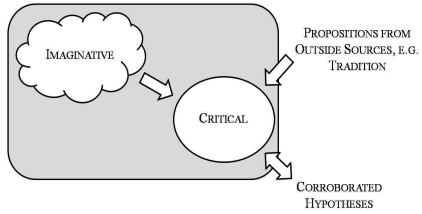


Fig. 1 - The Simple Popperian Scientist

The simple Popperian scientist fulfils two functions (which fall inside the grey area in Fig. 1): one imaginative, and the other critical.[15] In short, the scientist uses propositions from outside sources (e.g. tradition and experience) to criticise hishypotheses (which are often derived from his imagination). The critical function may involve several procedures, e.g. non-empirical checks for internal consistency as well as empirical tests. Those hypotheses that survive the process count as corroborated (and are outputs). But simply because a hypothesis is corroborated, this does not mean that it is no longer subject to the critical function (and hence the bidirectional arrow between 'critical' and 'corroborated hypotheses').

There is, however, one rather striking feature of the Popperian scientist so depicted; he is purely theoretical in orientation. This appears to be the correct view of Popper's position because he suggests that applied science is the province of 'normal scientists':

[The normal scientist] has become what may be called an applied scientist, in contradistinction to what I should call a pure scientist. He is, as Kuhn puts it, content to solve 'puzzle s'··· it is not really a fundamental problem which the 'normal' scientist is prepared to tackle: it is, rather, a routine problem, a problem of applying what one has learned··· (Popper 1970, p. 53)

So what should we think of Popper's mention of dogmatism? If we imagine this as a function at the individual level, we will arrive at a somewhat different view from that depicted in Figure 1. Instead there will be a 'dogmatic filtering' function, in addition to the critical and imaginative functions, which will serve to ensure that some propositions - and in particular, some theories - are not criticised. As we can see from Figure 2, however, it is unclear that such a filter need be 'dogmatic' in any strong sense of the word. This is because the filter may function such that no (empirical) theory is in principle immune to being passed on to the critical procedure. So if a theory is brand new, for instance, perhaps it will be shielded from criticism until it can be further developed (by the imaginative, or creative, function); hence the bidirectional arrow between the imaginative and filtering functions. But if a theory is well-developed, i.e. has had a lot of imaginative effort spent on it, perhaps it will always pass through the filter.[16]

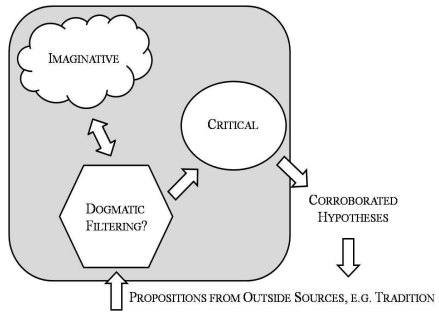


Fig. 2 - The Sophisticated Popperian Scientist

Let us now compare this with the Kuhnian normal scientist. In contrast to her Popperian counterpart, her primary function is to solve puzzles. And in order to do this, she relies on established scientific theories and data. (We should allow that some of the data used may not itself be a product of science. However, in so far as observations are heavily theory-laden, on Kuhn's view, it is likely that said data will be given an interpretative slant - and/or that what counts as

15) Bartley (1984, pp.182–183) emphasised the importance of creativity, i.e. the imaginative function, as follows: '[A]n essential requirement is the *fertility* of the econiche: the econiche must be one in which the creation of positions and contexts, and the development of rationality, are truly inspired. Clumsily applied eradication of error may also eradicate fertility.'

16) There may also be other ways to set up filters, e.g. to determine which theories or auxiliaries are attacked first. See Rowbottom Forthcoming B.

admissible data will be determined - by the disciplinary matrix.) The output of puzzle solving is both theoretical and concrete; that is to say, Kuhn does not draw a sharp distinction between 'pure' and 'applied' science in the manner that Popper does.

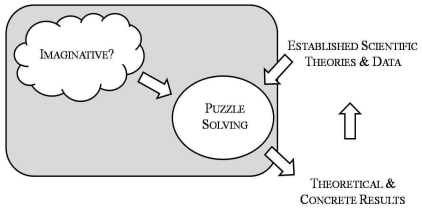


Fig. 3 - The Prima Facie Kuhnian Normal Scientist

We might wonder, though, whether good puzzle solving doesn't require a good degree of imagination, and therefore if the imaginative function is not also, as depicted in figure 3, a required component of the Kuhnian scientist. Despite first appearances, a somewhat closer look at Kuhn's position appears to suggest that it is not, because exemplars provide templates for puzzle solving. As Bird (2004) puts it:

In the research tradition it inaugurates, a paradigm - as - exemplar fulfils three functions:

(i) it suggests new puzzles;
(ii) it suggests approaches to solving those puzzles;
(iii) it is the standard by which the quality of a proposed puzzle-solution can be measured.[17]

To remove the 'imaginative' function from the picture is not to suggest that puzzle solving does not require considerable ingenuity, on occasion, nor to concede that it is as 'routine' as Popper (1970) suggested. The point is simply that an incredibly difficult puzzle is still little more than a puzzle when the rules of the game and procedures for playing are all fixed. And Kuhn certainly does not suggest that (normal) scientists require anything like '"an irrational element", or a "creative intuition", in Bergson's sense' (Popper 1959, p.32). In the words of Kuhn (1963, p. 362):

The paradigm he [the normal scientist] has acquired through prior training provides him with the rules of the game, describes the pieces with which it must be played, and indicates the nature of the required outcome. His task is to manipulate those pieces within the rules in such a way that the required outcome is produced.

We are therefore left with the picture below, depicted in Figure 4, in which exemplars remove the need for an imaginative function. (It is worth adding that an imaginative function may be required in extraordinary science, e.g. in order to bring exemplars in to being, but that we are not presently concerned with this.)

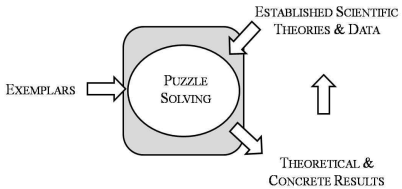


Fig. 4 - The Kuhnian Normal Scientist

Figure 4 does run the risk, however, of making Kuhn's picture look rather simpler than it actually is.[18] This is because many different activities fall under the rubric of 'puzzle solving', as Kuhn explains in chapter three of 'The Structure of Scientific Revolutions.' So figure 5 gives a look inside the puzzle solving function, and shows that it is composed of several different processes. For a full discussion of these processes - classification and prediction, theory-experiment alignment, and articulation - see Rowbottom Forthcoming A. For present purposes, it suffices to note that these are significant functions within the function of puzzle solving.

17) See also Rowbottom Forthcoming A, Bird 2000, pp. 68-69 and Hoyningen-Huene 1993.

18) The charge could equally be made that the critical function, in Popper's model, is composed of other functions. I accept this, however, as will be made apparent below.

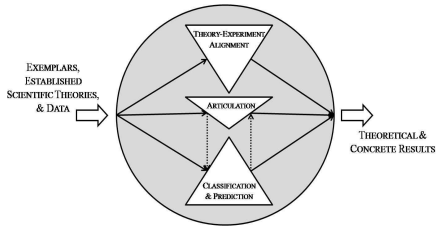


Fig. 5 - Inside Puzzle Solving

We have now seen that despite their strikingly different views of the ideal scientist, both Popper and Kuhn had understandings that can be modelled with ease via a functional perspective. For both, to be a good scientist is simply to perform specific functions. And good science is to be understood as an activity performed by large numbers of good scientists in precisely the aforementioned sense.

However, this functional analysis makes the following questions, which we will come to in the next section, salient. Why not have different functions performed by different scientists? And why not entertain the possibility that it is (sometimes) necessary for the functions be performed by different individuals in order for science to be (or to be as close as possible to) ideal?

6. Functions at the Group Level: A Hybrid Model

Moving to a consideration of functions at the group level allows us to consider, first and foremost, the possibility that both dogmatism and criticism are vital components of the scientific enterprise. And while it may be suggested that Kuhn would have agreed in so far as criticism might play a crucial part in extraordinary science, his picture is one where science should go through different phases. In short, his view appears to have been that either all scientists should be doing normal science, or all scientists should be doing extraordinary science. The possibility that it might be preferable for the two kinds of activity to co-exist, in so far as some might be dogmatic and others might be critical at the same time, was never dismissed on adequate grounds. Neither Kuhn nor Popper examined this possibility in any serious depth; the former because of his belief in the importance of revolutions (derived from his historical studies), and the latter because of his long-standing belief in the importance of criticism.[19]

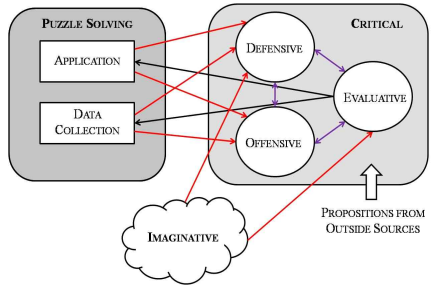


Fig. 6 - A Hybrid View of Science at the Group Level

Allow me to start by giving an overview of Figure 6, which may initially appear impenetrable. According to this model, (ideal) science involves each of the three primary functions discussed previously: imaginative, puzzle solving, and critical. The imaginative function provides some objects of criticism, which may be evaluated and rejected, or defended, attacked, and then subsequently evaluated. (Note also that said evaluation may rely on propositions from outside sources, e.g. tradition, too.) The critical function has three parts: offensive, defensive, and evaluative. These should be reasonably self explanatory, but will be illustrated in the course of the subsequent discussion.

Now it is crucial to distinguish between critical procedures (or methods) and the critical attitude. That is to say, it is possible for science to perform a critical function with wide scope even when none of its participants have (completely) critical attitudes. One simple way to see this is to imagine a scenario in which each scientist holds different assumptions dogmatically, but in which no peculiar assumption (qua proposition or theory) is held dogmatically by all scientists. So at the group level no statement is beyond criticism.

19) Thus it took Feyerabend (1970, p.212) to suggest that 'the correct relation is one of *simultaneity* and *interaction*.'

We can develop this idea by considering another simple scenario in somewhat greater depth. Imagine two dogmatists, D_1 and D_2, who are dogmatic only in so far as they will do any thing to defend their individual pet theories, T_1 and T_2, which are mutually exclusive. So D_1 will *defend* T_1 at all costs, e.g. by challenging auxiliary statements used to generate predictions from T_1 in the event of the possibility of empirical refutation, just as D_2 will defend T_2. (This is fulfilling a *defensive* function.) To the death, neither D_1 nor D_2 will abandon their respective pets. But each will try to persuade other scientists–whether or not they try to persuade one another–tha ttheir own pet is superior. And as part of this, said dogmatists need not only defend their own pets against attack, but may also attack the rival pets of others. So part of D_1's strategy to promote T_1 may be to attack T_2, just as part of D_2's strategy to promote T_2 may be to attack T_2 (i.e. to fulfil an *offensive* function). Thus both dogmatists may fulfil (narrowly focused) critical functions of attack and defence.

But if everyone were such a dogmatist, stalemate (and perhaps even disintegration of science) would ensue. This is why a third critical function, that of evaluation, is crucial in order to judge whether T_1 or T_2 emerges victorious. Needless to say, such an evaluative function may be performed by interested third parties who are not themselves committed to either T_1 or T_2. So note that a third dogmatic scientist, D_3, who is set upon defending a theory T_3 which may stand irrespective of whether T_1 or T_2 is correct, may serve as an evaluator of the debate between D_1 and D_2. In short, to attack or defend as a result of dogmatism in one context does not preclude evaluating in another.

But how might dogmatic individuals benefit science in a way that their completely critical (and/or highly evaluative) counterparts might not? The simple answer is that they may be far more persistent in defending their pet theories (and therefore attacking competitor theories) than a more critical individual could be. So they might, for example, consider rejecting auxiliary hypotheses when their critical counterparts would not (and would instead simply reject a theory). But it is well worth re-emphasising that being dogmatic in this sort of sense does not preclude being critical. Rather, the critical activity of such an individual will have narrow scope; it will be aimed only at defending pet theories, and attacking competitor theories. So in short, to be critical in some small area is still to be critical, even though it is not necessarily to have the critical attitude that 'I may be wrong and you may be right, and by an effort, we may get nearer to the truth' (Popper 1945, vol. II, p.249), or to be a pan-critical rationalist in the sense of Bartley (1984). Just as there are occasions where 'a commitment to the paradigm was needed simply to provide adequate motivation' (Kuhn 1963, p. 362), there may be occasions where dogmatic commitment is crucial in order to push the scientist to consider avenues that would be ruled out by more evaluative individuals. My point here is that territory may be explored which would otherwise not be, and that this might result in a variety of fruits; I do not join Kuhn (1996, p.247) in thinking that such exploration will, as a general rule, be successful in isolating 'severe trouble spots'.

Furthermore, it may be a good thing for individual scientists to devote themselves to performing a small number of functions.[20] Perhaps, for instance, it is extremely difficult (due to human limitations) to be an expert puzzle solver and an expert attacker. Perhaps, in deed, the kind of person who is an expert attacker is often a lousy puzzle solver (because he or she finds it hard, qua boring, to work with externally imposed frameworks of thought or to perform repetitive tasks). So here we might say that something like van Fraassen's (2002, 2004a, 2004b) notion of a stance is relevant, especially if we think of this as involving mode of engagement and a style of reasoning (Rowbottom and Bueno Forthcoming). One scientist's style may be to think outside the box, and he might engage by performing wild new experiments or working on highly abstract theories. Another scientist's style may be to think inside the box, and she may engage by repeating well-known experiments (with minor refinements). And trying to force either scientist to change style or mode may be unwise. Indeed it may not even always be possible for such changes to occur.[21]

In closing this section, we should also consider how the puzzle solving function may relate to the critical one. (Consider, again, figure 6.) First, only theories which are positively evaluated (by those performing the evaluative function) will be used for puzzle solving purposes. It is these theories that will be applied, and which will determine what sort of data is normally considered to be worthy of collection. Second, however, the puzzle solvers' data and results may be useful to those who are performing attacking and defensive critical functions. (Attempts to puzzle solve may isolate unanticipated trouble spots, for example, just as Kuhn suggested.) Third, the results of the attacking and defending processes will be evaluated, and this will determine what sort of puzzle solving takes place next. So in short, there may a fruitful interchange between puzzle solvers and criticisers; and perhaps this is the genuine lifeblood of science.

7. Further Questions

The model proposed above raises a quite different set of questions from those explicitly tackled by Kuhn and Popper, and shifts the focus of the debate. How should the balance between functions be struck? That is to say, for any given group of scientists, how many should be fulfilling puzzle solving functions, rather than critical functions? And of those performing critical functions, how many should, say, be performing evaluative functions? These questions, and others like them, may not have 'hard and fast' answers that are contextually invariant. Instead, the proper distribution of activity may depend on the skill base available - e.g. perhaps despite their best efforts, some people cannot feign being dogmatic when they are not, in so far as they cannot really push themselves to defend a theory come what may - and also the state of science at the time. If T_4 were evaluated as suffering from severe defects but there was nothing else available to put in its place, for instance, then perhaps more imaginative effort would be required. Similarly, if T_5 remained untested and unchallenged, then perhaps more offensive and defensive interplay concerning T_5 would be merited. (So note also that the wisdom of occasional episodes resembling revolutions, but not quite so extreme and wide-ranging as Kuhn's model demands, may be accounted for.)

I should emphasise that I have not denied that there is a fact of the matter about what an individual scientist might best do (or best be directed to do) in a particular context of inquiry. Rather, I have suggested that determining what this is requires reference not only to the state of science understood as a body of propositions (or as knowledge) but also to what other scientists are doing and the capacities of the individual scientist. Consider a new professional scientist, going into his first postdoctoral research project; and let his capacity for good work be fixed by his interests, desires, and experience. Assume he could work just as well in group B as in group A. It might be preferable for him to join A because its line of inquiry is more promising than that of B, on current indicators, although it has fewer members.[22] So in short, I take there to be measures - even if they are rough measures, such as Popper's corroboration function[23] - of how theories (and/or research programmes, modelling procedures, etc.) are faring. And these, given the resources at our disposal, determine how we should respond.

A simple analogy may help. Imagine you, the chess player, are managing science. The pieces are the scientists under your command, and their capacities vary in accordance with their type (e.g. pawn or rook). The position on the board - nature is playing the opposing side - reflects the status quo. And now imagine you are told that, against the rules of normal chess, you are allowed to introduce a new pawn (which you can place on any unoccupied square).[24] (This is

20) An interesting objection to the picture shown in Figure 6, indeed, is "Why should each and every scientist not perform all of *those* functions?" This question was put to me when I presented this paper at the Future of Humanity Institute, Oxford.

21) In fact, as I argue in Rowbottom Forthcoming A, appeal to something like stances is necessary for Kuhn irrespective of whether any concessions are made on the issue of criticism. In particular, appeal to stances can explain how different activities occur within a disciplinary matrix, i.e. account for the differences in puzzle-solving activity. For example, they can explain why one scientist endeavours to articulate a theory, whereas another seeks only to apply it in unproblematic circumstances, or why two different scientists look to different exemplars (and therefore puzzle solving strategies) to tackle one and the same puzzle.

22) Note that this doesn't depend on assuming that what everyone else (other than the individual) is doing is fixed. The best thing to do might be to have the newcomer replace a particular scientist in A, so that she could be moved to B, and so on. Think of the newcomer as an added resource.

23) For an extensive discussion of this, see Rowbottom Forthcoming C.

24) Incidentally, there are variants of chess, such as Crazyhouse chess, where this sort of thing is possible.

akin to the introduction of a new scientist; pieces working in combination on your side can be thought o f as research groups, and so on.) Some moves will be better than others, given your aim of winning the game, and in some circumstances it will be clear that one available move is best.

So my own view is that considering social structure neither precludes employing insights from what might be called the 'logical' tradition in the philosophy of science - formal apparatus, such as confirmation or corroboration functions, for instance - nor requires acceptance of the view that studies in scientific method always require reference to the history of science. Social structure is relevant to questions of scientific method; but it is hardly as if when we discuss groups, rather than individuals, we suddenly find ourselves in territory where the 'logical' tradition has nothing to offer. [25)]

The picture presented in this paper is complex, and the questions enumerated in this concluding section are daunting. It may prove to be the case that they are beyond our power to answer satisfactorily except in highly idealized contexts. Nevertheless, it appears that complexity is necessary if we are to truly get to grips with the question of how science should work. At the very least, the model here considered, e.g. as presented in figure 6, provides a basic framework with which to tackle practical questions when considering the research activity of a group (or groups). And even if that model is rejected, to consider functions at the level of the group is arguably to make an important conceptual breakthrough in understanding (and therefore shaping) science. If there is one message to take away, it is that ideal science may be realizable in more than one way.

Acknowledgements

I should like to thank Peter Baumann and two anonymous referees, as well as audiences at the Future of Humanity Institute and Ockham Society (both at the University of Oxford), for comments on earlier versions of this paper. This is an output from my 'Group Rationality and the Dynamics of Inquiry' research project, funded by the British Academy via their Postdoctoral Fellowship scheme.

25) I say this in part because one commentator on the ideas in this paper, who works in the 'logical' tradition, reacted by declaring that "Kuhn was [just] a sociologist". Not only is this wrong - as Jones (1986) shows - but also remarkably myopic.

[References]

Bartley, W. W. 1984. The Retreat to Commitment (2nd Edition, LaSalle: Open Court)

Bird, A. 2000. Thomas Kuhn (Chesham: Acumen)

Bird, A. 2004. 'Thomas Kuhn', , E. N. Zalta (ed.) (URL: http://plato.stanford.edu/archives/fall2004/entries/thomas-kuhn/)

Diller, A. 2008. 'Testimony from a Popperian Perspective', Philosophy of the Social Sciences 38, 419-456.

Domondon, A. T. In Press. 'Kuhn, Popper, and the Superconducting Supercollider', Studies in History and Philosophy of Science.

Duhem, P. 1954. The Aim and Structure of Physical Theory (Princeton: PUP)

Feyerabend, P. K. 1970. 'Consolations for the Specialist', in Lakatos & Musgrave 1970, pp. 197-230

Fuller, S. 2003. Kuhn vs. Popper: The Struggle for the Soul of Science. London: Icon Books.

Gattei, S. 2008. Thomas Kuhn's "Linguistic Turn" and the Legacy of Logical Empiricism. Aldershot: Ashgate.

Hoyningen-Huene, P. 1993. Reconstructing Scientific Revolutions: Thomas S. Kuhn's Philosophy of Science (Chicago: University of Chicago Press)

Hull, D. L. 1988. Science as a Process: An Evolutionary Account of the Social and Conceptual Development of Science (Chicago: University of Chicago Press)

Kitcher, P. 1990. 'The Division of Cognitive Labor', Journal of Philosophy 87, 5-22

Kuhn, T. S. 1963. 'The Function of Dogma in Scientific Research', in A. C. Crombie (ed.), Scientific Change (New York: Basic Books), pp. 347-369

Kuhn, T. S. 1970a. 'Logic of Discovery or Psychology of Research?', in Lakatos & Musgrave 1970, pp. 1-23

Kuhn, T. S. 1970b. 'Reflections on my Critics', in Lakatos & Musgrave 1970, pp.231-278

Kuhn, T. S. 1977. The Essential Tension: Selected Studies in Scientific Tradition and Change (Chicago: University of Chicago Press)

Kuhn, T. S. 1996. The Structure of Scientific Revolutions (3rd edition, Chicago: University of Chicago Press)

Jones, K. 1986. 'Is Kuhn a Sociologist?', British Journal for the Philosophy of Science 37, 443-452

Lakatos, I. and Musgrave, A. (eds) 1970. Criticism and the Growth of Knowledge (Cambridge: CUP)

Musgrave, A. 1974. 'The Objectivism of Popper's Epistemology', in P. A. Schilpp (ed.) 1974, The Philosophy of Karl Popper (La Salle, IL: Open Court), pp. 560-596.

Popper, K. R. 1940. 'What is Dialectic?', Mind 49, 402-436

Popper, K. R. 1945. The Open Society and its Enemies (London: Routledge)

Popper, K. R. 1959. The Logic of Scientific Discovery (New York: Basic Books)

Popper, K. R. 1963. Conjectures and Refutations (London: Routledge)

Popper, K. R. 1968. 'Remarks on the Problems of Demarcation and of Rationality', in I. Lakatos & A. Musgrave (eds) 1968, Problems in the Philosophy of Science (Amsterdam: North-Holland)

Popper, K. R. 1970. 'Normal Science and its Dangers', in Lakatos & Musgrave 1970, pp. 51-58

Popper, K. R. 1975. 'The Rationality of Scientific Revolutions', in R. Harré (ed.), Problems of Scientific Revolution, pp. 72-101.

Rowbottom, D. P. 2006. 'Kuhn versus Popper on Science Education: A Response to Richard Bailey', Learning for Democracy 2, 45-52.

Rowbottom, D. P. Forthcoming A. 'Stances and Paradigms: A Reflection', Synthese (DOI: 10.1007/s11229-009-9524-x).

Rowbottom, D. P. Forthcoming B. 'Corroboration and Auxiliary Hypotheses: Duhem's Thesis Revisited', Synthese (DOI: 10.1007/s11229-009-9643-4)

Rowbottom, D. P. Forthcoming C. Popper's Critical Rationalism: A Philosophical Investigation. London: Routledge.

Rowbottom, D. P. and Bueno, O. Forthcoming. 'How to Change It: Modes of Engagement, Rationality, and Stance Voluntarism', Synthese (DOI: 10.1007/s11229-009-9521-0).

Strevens, M. 2003. 'The Role of the Priority Rule in Science', Journal of Philosophy 100, 55-79

van Fraassen, B. C. 2002. The Empirical Stance (New Haven: Yale University Press)

van Fraassen, B. C. 2004a. 'Précis of The Empirical Stance', Philosophical Studies 121, 127-132

van Fraassen, B. C. 2004b. 'Replies to discussion on The Empirical Stance', Philosophical Studies 121, 171-192

Watkins, J. 1970. 'Against "Normal Science"', in Lakatos & Musgrave 1970, pp. 25-37

▪ Keynote Speech 4 13:30-14:30 / Dec. 17, 2016 / Conference Hall

Modern physics education for the masses

Kim, Chan-Ju, Ewha Womans University, Korea
✉ cjkim@ewha.ac.kr

Abstract

I first report my experience in teaching modern physics as a liberal arts course for more than ten years. The number of students registering the course is usually 290 per semester. They are from all possible majors including humanities and arts. The course starts with classical physics of Newton and Maxwell. Then concepts in relativity and quantum mechanics are discussed fairly in detail. They are followed by various topics such as statistical physics, network sciences, arts, and symmetries. The course closes with the current status of high-energy physics and cosmology. Throughout the course, the physical motivation and the logical flow is emphasized without resorting to any mathematical formula. An online version of the course has been developed and opened in the K-MOOC (Korean MOOC) site recently initiated by the Korean government. I discuss issues and difficulties encountered in converting the offline course to the online version.

Keywords: physics education; modern physics; science as a liberal art; online course; MOOC

1. Modern physics as a subject for effective teaching of scientific reasoning to the masses

Modern physics such as relativity or quantum mechanics is notorious of its counterintuitive results and difficult mathematics involved with it. However, I believe that, if properly taught, modern physics can be served as one of the best subjects with which students can be acquainted with the scientific view of the world. Actually compared to other fields in science, it is unique in that the core concepts of relativity and quantum mechanics can be understood without any prior knowledge in science or mathematics because they are largely based on thought experiments such as Einstein's train, Einstein's elevator, and double slit experiments. This talk is a report about pursuing this idea for more than 10 years.

In this talk, I would like to describe my experience in teaching modern physics as a liberal arts course, both offline and online. Since 2005, I have been teaching a one-semester course "Modern physics and the revolution of human thought" in Ewha Womans University, Seoul, Korea. The aim of the course is to expose students to the scientific view of the world - a unified view from quark to the universe and from big bang to the current universe. In particular, it is emphasized throughout the course that science is not merely a collection of independent explanations on various phenomena. Another goal is to help students regain imagination and curiosity lost in high school due to fierce competition to enter the college.

The course was designed to be accessible to any student at Ewha including those from humanities, social sciences, arts, and athletics as well as physics, natural sciences and engineering. In order for this to be possible, no mathematics is used throughout the course and no prior knowledge on physics is assumed, either. This does not, however, mean that the course is easy. Topics are carefully selected and presented to expose students to the core reasoning of theories in modern physics to the extent that they are not usually taught at this introductory level. In the talk I will illustrate some examples.

2. The course: Modern physics and the revolution of human thought

2.1. Course design philosophy

This course consists of 3-hour lectures per week for 15 weeks. It is designed to include most of the major developments in modern physics. Since at least half of the students are not science majors, no prior knowledge in physics or mathematics is assumed. In addition, the following items were considered in preparing the course:

- Step by step explanations with a concrete representative example.
- Let students feel the flow of logic. They often frustrate when there is an obvious logical jump in the explanation. Give at least heuristic arguments.
- Utilize various form of media such as picture, sound, movie, animation, and virtual experiments with flash or java.
- Perform simple on-site experiments.
- Encourage questions and online discussions.

2.2. Course synopsis

The syllabus is mainly divided into four parts: (i) preparation (ii) revolution (iii) expansion (iv) new challenges. Since most students have no background on physics, the class starts with classical physics with particular emphasis on the concepts of the particle and the wave, and how they are related through the oscillation. Then the concept of field, which is often omitted in this kind of course, is explained. Electric and magnetic fields are visually illustrated. Intuitively the variation of electric field lines would generate a wave which is the electromagnetic wave, i.e. the light.

Part (ii) is the main part of the course. Students will learn about relativity, quantum mechanics and their applications to our daily life. Starting from the two basic postulates in special relativity, various relativistic effects are derived through Einstein's thought experiment with train. All the necessary logical steps are provided with great care and for sufficient amount of time so that students can appreciate the inevitability of special relativistic effects such as time dilation, length contraction, twin paradox and so on. This is followed by the thought experiment in the elevator and equivalence principle of general relativity. As for the quantum mechanics, a one-hour lecture is dedicated to the famous double slit experiment. Students will be frustrated by the fact that they cannot understand the behavior of electron or photon. But then the experience of frustration would lead them to accept the probabilistic interpretation in quantum mechanics.

In part (iii), various every day phenomena around us are discussed. First, the concept of entropy is explained in detail from the viewpoint of statistical mechanics, which is naturally connected to the arrow of time in the light of the second law of thermodynamics. It is followed by an introduction to the physics of complex systems such as chaos, fractal, synchronization, network sciences, and econophysics. The second half of part (iii) deals with music, art, and their relation to physics.

The course ends in part (iv) with an introduction to the physics of fundamental matters and cosmology, including the standard model in particle physics, string theory, big bang theory, dark matter, and dark energy.

2.3. K-MOOC

In 2015, the Korean government launched the so-called K-MOOC (Korean MOOC) site and this course was selected as one of 26 pilot courses. This course was converted to an online lecture and was recorded in a studio at Ewha. Since real-time communication is not possible in MOOC, the course materials had to be modified accordingly.

3. Results

In spring semester 2015, which was the first semester this course was open at Ewha, the number of students was 33

which barely exceeded 30, the minumum number to open a liberal art course at Ewha. But, in the next semester, 133 students took the course, which is exactly 100 students more. Since 2009, the number of students has been fixed to 290 which is the number of seats of the lecture hall. Roughly half of the students are from science non-majors such as humanities, social sciences, and arts. The responses of the students have been mostly positive. The course has been awarded 5 times for one of the best lectures in Ewha. In the project searching 100 best college lectures in Korea, it was also selected as one of the first five lectures to in the list in 2012.

More than 10 year of statistics shows that the grade distribution is not much dependent on the background knowledge or majors of the students. The performance of science (or even physics) majors is not particularly better than others. This shows that the original idea of the course is operating well.

The online lecture at K-MOOC was taken by about six thousand people with various backgrounds, from elementary school students to elderly people in seventies. Among the 26 pilot K-MOOC courses, this course got the most positive feedback in the course evaluation by students. This implies that even to the general public, modern physics can be an ideal subject with which they can turn their eyes to the scientific worldview.

PRE-CONFERENCE WORKSHOP

▪ Preconference Workshop 1 10:30-12:30 / Dec. 15, 2016 / Conference Hall

Researching and publishing in HPS&ST

Michael R. Matthews, University of New South Wales, Australia
✉ m.matthews@unsw.edu.au

This workshop will outline general requirements expected to be meet for published education research as itemised by the US National Research Council. It will elaborate more specifically the requirements for publication in the area of HPS&ST, drawing on my experience of 25 years of editing Science & Education journal. Examples will be given of reviewers' comments on rejected manuscripts in order to illustrate how not to write for publication. Accounts will then be given of good writing, with specific emphasis on the writing of clear and understandable text. Finally the reality and associated problems of the 'publish or perish' regime in universities will be discussed.

▪ Pre-conference Workshop 2-1 14:00-16:00 / Dec. 15, 2016 / Conference Hall

A method of conducting informal science education from POE to POE2C

Chen, Nelson, National Science and Technology Museum, Taiwan
Park, Young-Shin, Chosun University
✉nelson@mail.nstm.gov.tw

POE, Prediction-Observation-Explanation, has been doubtless applied and conducted in science-related field for decades, nevertheless, what will it further be? This paper aims to develop a newly-enhanced method to modify from POE to POE2C, Prediction- Operation, Explanation, Comparison and Contest. In short, science learning doesn't only focus on the knowledge learning of science, but it also extends to raise a comparison of new and old science concept, and a creative capability of the science application. 12 Taiwanese and Korean interns performed at the course of pre-training, then , 42 gifted students of secondary school, divided into 6 groups, participated a 3-day science winter camp at science museum, a venue of Informal Science Education, in 2015 , the steps of conducting the course with POE2C are as follows: (1) Prediction: Tutor demonstrated a magic show with science, ask the pupils to guess and write what was going on; (2) Operation: All of attendees were given a set of materials for practically and personally operating to trace the reason of step; (3) Explanation: Teacher explained the reason of what kind of science concept was applied; (4) Comparison: Students compared the original concept at step 1 and the latest concept at step 3, try to find the change of concepts it may alter or be different; and (5) Contest: Each of group developed its own newly-created game or science show for a contest with others to enhance student's capability of creativity. A cooperative learning approach was applied and a semi-structured questionnaire was raised for all participants to fill out anonymously. The results of outcomes, such as newly-invented ideas for science, the capability of comparison, cooperation, communication, leadership, curiosity, imagination and creativity and so on, have significantly increased from less to many and been praised by the participants .

Keyword: POE, POE2C, Science museum, Cooperative Learning, Informal Science Education

▪ Preconference Workshop 2-2 14:00-16:00 / Dec. 15, 2016 / Rm 209

Making Drone and STEAM

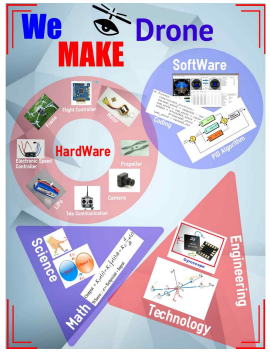
Kim, Jaekwon, Munsu High School
✉ kjk27290@gmail.com

- The digitisation of manufacturing will transform the way goods are made and change the politics of jobs too1· We should be framing things in our schools not just in terms of "how do we test you on that?" but on "what can you do with what you know?"

- People construct new knowledge with particular effectiveness when they are engaged in constructing personally meaningful products3

- In making Drone, there are a lot of challenging factors of Science, Technology and Engineering. These can fertilize young student's maker mind set.

- To be Drone making successful, it is inevitable to be harmony with Personnel, financial, technological and space supports.



- ► Time Duration : 50 minutes(09:30~10:20)
- ► Expected attendance : 10~15 persons
- ► Time table

Time table	Contents	Remarks
09:30~10:00	How to make drone take-off ? **FPV Drone assemble & landing Activity**	Activity
10:00~10:10	Story of Two K-11 students **Human Rescue Drone Prototype**	Talk
10:10~10:20	Case Study: **Module Based STEAM Curriculum**	Presentation

[Reference]
1. The Economist(2012), The third industrial revolution, Apr 21st 2012
2. Dale Dougherty (2012), The Maker Movement, innovations, vol 7,No3
3. John Donalson(2014), The Maker Movement and Rebirth of Constructivism, http://www.digitalpedag

ORAL PRESENTATION

▪ ORAL PRESENTATIONS - 1A

09:00-10:30 / Dec. 16, 2016 / Rm 203

Indonesian pre-service biology teacher's evolutionary knowledge and reasoning patterns

Rachmatullah, Arif, Kangwon National University, Indonesia
Nehm, Ross, Stony Brook University, USA
Ha, Minsu, Kangwon National University, Korea
Roshayanti, Fenny, University of PGRI Semarang, Indonesia
✉*arifraach@gmail.com*

Cross-cultural studies have served as an important research approach for gleaning insights into the roles that religion, culture, and formal education differentially play in the development of evolutionary knowledge, acceptance, and reasoning models in students and teachers. Indonesia has received little attention in the evolution education research community even though it is the world's third most populous democracy and the world's largest Muslim-majority nation (CIA, 2016). As such, Indonesia has the potential to provide unique insights into the ways that religion, culture, and formal education contribute to evolutionary understanding and reasoning patterns. Unlike many other democracies, religion is a central feature of formal education. Indeed, religion is woven throughout the newly published Indonesian school curriculum. Many core claims in the growing field of evolution education—such as the relationship between knowledge, acceptance, and religion--have been based on studies of American, Turkish, and Korean students and pre-service teachers. Studies of evolutionary reasoning processes (that is, how cognitive resources are mobilized to solve different types and forms of evolutionary scenarios -such as the gain and loss of traits in animals and plants) are almost exclusively from American samples. Core insights could be gained from empirical studies investigating knowledge and reasoning patterns in broader array of participant samples. Our study seeks to gain such insights from a large-scale, mixed methods study of Indonesian pre-service biology teachers' reasoning. We use carefully translated and empirically validated measurement instruments to compare reasoning patterns and levels. We performed two kinds of studies. Given space limitations, we only discuss some of our findings. The first study (Study 1) was quantitative and statistically compared the composition and structure of Indonesian and American evolutionary reasoning patterns across different problem types. The total number of research subjects in Study 1 was 529 participants, including 321 American undergraduates (years 1, 2 and 4) and 208 Indonesian pre-service biology teachers (years 1, 2, 3 and 4). The second study (Study 2) was qualitative and aimed to provide a richer and deeper understanding of evolutionary reasoning patterns in a sample (n = 22) of Indonesian pre-service teachers. In order to explore evolutionary reasoning patterns, we employed the ACORNS instrument (Assessment of COntextual Reasoning about Natural Selection), which is designed to uncover levels of expertise based on evolutionary problem-solving proficiency across items differing in scale, taxon, trait, familiarity, and polarity. We used four ACORNS items in both studies, but in different ways.

In Study 1, we analyzed written ACORNS responses and in study Study 2 we analyzed clinical interview data. Based on Study 1, compared to the American sample, Indonesian pre-service biology teachers had significantly lower numbers of total normative key concepts across all problem types. In addition, the Indonesian teachers had significantly higher total naïve ideas across all problem types. In terms of the specific types of key concepts of evolutionary theory employed, Indonesian pre-service biology teachers utilize similar types of knowledge as the Americans for the concept of variability. But, for the other two key concepts--heritability and differential survival/ reproduction -Indonesian pre-service biology teachers used them much more rarely. In terms of other key concepts, the Indonesian and American samples displayed similar patterns, which were high use of limited resources and low use of competition and population change. Indonesians displayed significantly greater naïve ideas than Americans on the concepts of adaptation/ acclimation and use-disuse inheritance. In the terms of overall explanatory model type (scientifically normative, mixed, naïve, or no model) Indonesians used significantly fewer scientific models and significantly more naïve and no models compared to Americans. One of the most interesting findings is that the types of ideas used to approach the problems were very similar despite substantial differences in culture and religion. In Study 2 we found that Indonesians have high cognitive biases, particularly in terms of teleology (Need/Goal) and surprisingly viewed use-disuse inheritance as an important component of evolutionary theory. Most of the Indonesian pre-service biology teacher sample assumed that environmental effects are the major drivers for evolutionary change. We will expand our findings and connect them with the cultural and educational contexts prevailing in Indonesia, with consideration of general science performance on international studies (such as PISA and TIMSS). We will also discuss how pre-service teachers' reasoning changes through the educational system.

Teachers' conceptions of models and modeling in science and science teaching: Ontological and epistemological analysis

Kang, Nam-Hwa, Korea National University of Education, Korea
✉*nama.kang@gmail.com*

Science inquiry has long been emphasized in Korean science education. Scientific modeling is one of key practices in science inquiry that has a potential to provide students with opportunities to develop their own explanations and knowledge thereafter. The purpose of this study was to examine teachers' conceptions of the nature of models and modeling in science and ways to use them in teaching science. A total of 29 elementary and secondary teachers were surveyed and observed during two-week long teacher professional development on models. Teachers' conceptions of models and modeling were categorized into three based on their ontological and epistemological grounds. In terms of ontological aspect, three levels of conceptual emphasis emerged: emphasis on physical or concrete nature, emphasis on representation of ideas or explanations, and emphasis on producing new ideas. Only the level three emphasis was related to constructive epistemological conceptualization of using models in science teaching. Most teachers demonstrated levels one and two in the beginning of the professional development and about one third of them extended their views after the short professional development. Nonetheless teachers' ideas about using models and modeling in science teaching were limited to demonstrating phenomena or assistance to explanation provision. Even the teachers who recognized the role of models in producing knowledge rarely mentioned using models in providing students develop their own explanatory models. Implications for science curriculum and teacher education are discussed.

Learning chemistry through designing digital games

Lay, Ah-Nam, National University of Malaysia, Malaysia
Osman, Kamisah, National University of Malaysia, Malaysia
✉ *layahnam@yahoo.com*

As science and technology innovations are increasingly important in the global economy market of the 21st century, Malaysia needs to produce students who master both the knowledge of chemistry and 21st century skills. At the same time, students must be highly motivated so that the learning becomes more efficient. However, chemistry is perceived as a difficult and unpopular subject. The Salt chapter in Malaysian Chemistry Curriculum is perceived the toughest chapter. Studies have also reported that students' 21st century skills and motivation in science are not encouraging. Previous studies have reported that digital game-based learning (DGBL) provides opportunities for increasing students' motivation in learning while enhancing their academic achievement and 21st century skills. In this study, we applied one possible approach to DGBL, which allow students to take on the role of game designers, developing digital games while learning chemistry. Based on this approach as well as the constructivist-constructionist learning theories, an intervention module, known as MyKimDG, was developed to assist students in learning of Salt chapter. A quasi-experimental study with

non-equivalent control group pretest-posttest control group design was carried out to investigate the effect of MyKimDG on students' achievement in the Salt chapter, motivation in chemistry and 21st century skills. Subjects were composed of 138 Form Four students from four secondary schools. Two schools were randomly selected as the treatment group and another two schools were assigned as the control group. Subjects in the treatment group learned the Salt chapter using the MyKimDG developed by the authors. On the other hand, the control group subjects were instructed in conventional method using learning materials mandated by the Ministry of Education. Instruments utilized in the study were the achievement test, the Malaysian 21st Century Skills Instrument (M-21CSI), and the Students' Motivation towards Science Learning (SMTSL) questionnaire. T-tests were conducted to evaluate the impact of the interventions on students' scores in the achievement test by group. Doubly MANOVAs were performed to investigate the group differences in 21st century skills and motivation in chemistry at two time points (pre and post interventions). Results showed a significant difference between the control group and treatment group in achievement in the Salt chapter. Results also revealed that the high productivity and self-efficacy scores improved significantly between pre-test and post-test for treatment group. Our results suggest that the inclusion of student as game designer approach in chemistry learning is able to improve the acquisition of chemical knowledge and 21st century skills while increasing motivation in chemistry.

▪ ORAL PRESENTATIONS - 1B 09:00-10:30 / Dec. 16, 2016 / Rm 204

South Korean teachers' conceptions related to the genetic determinism of human performances

Seo, Hae-Ae, Pusan National University, Korea
Castéra, Jérémy, Aix-Marseille University, France
Clément, Pierre, Aix-Marseille University, France
✉*haseo@pusan.ac.kr*

Genetic determinism of human behaviors from a viewpoint of reductionism is considered as a philosophical perspective that genes in human determine biological as well as social traits. With DNA structure discovered, more attempts have been tried to explain genes as elements of determining complicate traits of human. However, such a genetic determinism from a viewpoint of reductionism discloses problematic and controversial aspects. On the other hand, many biologists agree that human traits are determined by interactions between genes and genes as well as between genes and environments. In this context, genetic determinism still affect on ideas of general public as well as research directions of biologists. According to Clément's KVP model (Clément & Carvalho, 2007; Castéra & Clément, 2012), teachers' conceptions of genetic determinism influence students' concepts of genes. The study intended to investigate teachers' conceptions to genetic determinism of human behaviors from a viewpoint of reductionism.
For this end, a questionnaire adopted from the previous research (Castéra & Clément, 2012) was administered to 308 teachers including 151 pre-service and 157 in-service of biology, Korean, and primary. Factor analysis was conducted to extract major factors and one-way ANOVA was employed to find out differences in extracted factors among different groups of teachers. Four factors were extracted from 14 items of questionnaire, including factor 1, a perspective of genetic determinism of gender differences in intellectual ability, social status, and emotional traits; factor 2, a perspective of genetic determinism of individual differences in intellectual ability; factor 3, a perspective of genetic determinism of individual differences in biological immune function and behavioral trait; and factor 4, a perspective of genetic determinism of ethenic differences. From the results of One-way ANOVA among teacher groups on four factors, first, it showed significant difference in factor 1 (F=3.325, p=.006), factor 3 (F=3.320, p=.006) and factor 4 (F=4.325, p=.001) due to their subject matters. It was also found that there was a significant difference between pre-service and in-service teachers in factor 1 (t=-3.938, p=.000) and factor 4 (t=-3.121, p=.002). Finally, region did not influence on teachers' conceptions of genetic determinism of human behaviors.

Bildung in higher science education. A new approach for postgraduate teaching

Kenklies, Karsten, University of Strathclyde, UK
✉*karsten.kenklies@strath.ac.uk*

There have been two different approaches towards the education of Postgraduate or Doctoral students in different disciplines: Whereas one approach treats those students as sufficiently educated to pursue their further studies almost exclusively on their own - maybe providing additional support if so wished, but not making it compulsory -, the other approach holds it to be necessary to engage even Postgraduate students in processes of formal learning and to demand a certain amount of credits to be gained within a doctoral study course.

However, recent debates within those countries who did so far subscribe to the first view have shown that their might be an increase in the number of those who believe there should be compulsory Postgraduate teaching and learning. But it is only on first view that this envisioned teaching now resembles that of those countries where Postgraduate teaching has always been very much normal. On a closer look, the content is very much different, as this new approach towards Postgraduate teaching is not discipline specific but rather academic in a more universal "scientific" way.
Using Germany as an example, this paper endeavours to

introduce not only those new approaches towards Postgraduate teaching and learning which supposedly are important for Science as well as Humanities doctoral students and which centre around the notion of a Scientific Bildung, but also tries to point out specific difficulties of those approaches. Based upon insights from the History as well as the Philosophy of Science and the theories of Bildung which have been developed within the continental tradition of educational thought, the paper aspires to outline possibilities and limitations of such an approach towards Postgraduate teaching.

Integrated science curricula: A consideration of history in light of the NGSS

Oliver, J. Steve, University of Georgia, USA
✉*soliver@uga.edu*

In the United States today, there is a major reform underway to implement the Next Generation Science Standards (NGSS) as the foundational model for future science curricula. Historical research in science education is a tool to examine previous curricular reform efforts in order to better understand the implementation of present-day reforms. In particular, historical research is a powerful tool to inform the enactment of NGSS because of the existence of a documents from across the 20th century pertinent to implementation of integrated science curricula. This presentation will present the results of a historical study designed to uncover and synthesize documents describing the design, implementation, and evaluation of integrated science curricula.

It has been suggested by scholars in science education that STEM education has become the overall goal of our field replacing scientific literacy. The term STEM has according to documents from the National Academy of Sciences "developed wide currency in US education and policy circles." STEM education has had a meaning conferred upon it that refers to curricula with an emphasis on student learning outcomes based in an integrated knowledge of science, technology, engineering and mathematics. In the NGSS, the meaning of STEM is framed in terms of Core Disciplinary Ideas, Cross-cutting concepts, and Scientific/ Engineering Practices. Further, the integration described by the NGSS creates a very complex description of interconnectedness with profound challenges for measuring student outcomes. The idea of integrated curricula, both between science and other disciplines as well as within the scientific disciplines, has a very long history in science education dating at least as far back as the beginning of the 20th century. And yet this historical record is neither well known nor is it one of successful implementation. In many cases grand goals have served to stimulate grand projects which do not survive to fruition. One of the most notable projects fitting this description was the Scope, Sequence and Coordination project conceived and developed within the US National Science Teachers Association (NSTA) during the late 1980s and early 1990s. But other reforms based focusing on integrating date back much further into the 20th century. This presentation will examine a procession of efforts conducted in US science education across the 20th century to create integrated science curricula.

This research should be of interest to conference participants who place significance on the study of the history of science education as a means to understand present-day reforms. This research provides guidance for implementation of complex interventions most prominently represented by the NGSS reforms that are currently taking place.

▪ ORAL PRESENTATIONS - 1C 09:00-10:30 / Dec. 16, 2016 / Rm 209

An interpretation of quantum mechanics about Surrealist paintings: The case of Rene Magritte

Jho, Hunkoog, Dankook University, Korea
✉*hjho80@dankook.ac.kr*

The relationship between science and art has been a prolonged issue in science and science education research. It is usually regarded as reciprocal, since the scientists and artists brought about interesting achievements such as perspective by optics, precious depiction of bodies by anatomy and universal laws by harmony. Moreover, both science and art encountered a similar shift in the twentieth century; from deterministic view (Newtonian mechanics) to undetermined and probabilistic view (quantum mechanics) in science, and from representation to expression in art. Especially surrealist paintings described the concepts of space and time in an interesting way, which is similar to modern physics. A great artist, Rene Magritte, made a number of paintings for the first half of the century while a few of scientists founded a circle and completed an interpretation of quantum mechanics in Copenhagen. Thus, this study aimed at comparing the worldview of Rene Magritte with that of Copenhagen interpretation and analyzing his paintings from a viewpoint of the Copenhagen interpretation. The Copenhagen interpretation was composed of five key ideas by Heisenberg: probabilistic wave function (Born rule), indeterminacy principle (or uncertainty principle), correspondence principle (wave-particle duality), ontological meaning of quantum phenomena (superposition of probabilistic wave functions), and non-instantaneous change in quantum phenomena (quantum jump). The paintings of Rene Magritte were accorded with the aforementioned features of the Copenhagen interpretation. The results showed that there are similarities between the two in terms of ontological stance about the reality and many of the paintings were viewed as inclusion of concepts related to quantum mechanics. Thus, this study tried to give some implications about how to combine science and art as an interdisciplinary education.

Scientific pluralism as a key epistemic value for the practice turn in science education

Park, Wonyong, Seoul National University, Korea
Song, Jinwoong, Seoul National University, Korea
✉*togumo@snu.ac.kr*

Being influenced by decades-long debate by scholars of science studies, science-as-practice now begins to attract increasing attention from science educators. Many educators have found teaching "the scientific method" no more valid in school settings, which made them turn their attention to what scientists actually do, rather than what they say or what they should do. Recent curricular reforms as the US Next Generation Science Standards also present the teaching of scientific practices as their key objective.

On the other hand, there is one recent issue among philosophers of science—scientific pluralism. Scientific pluralism is crudely defined by such ideas that there exists no single correct approach which fully explains the entire natural events and phenomena, and that this plurality is not a temporary nor immature state of affairs but in fact a desired value of science. Advocates of scientific pluralism have various points of emphasis, ranging from the plurality of scientific methods and theories to that of systems of practice.

In these regards, this study explores the place of scientific pluralism in the practice turn of science education, and argues that such different forms of pluralism can function as a key epistemic value in the science education. Critical analyses of science curricula and textbooks are presented to support that little attention is given to the pluralism in today's school science. We conclude by offering a case history in which plurality of physical sciences becomes explicit, and discussing its possible benefits for science education.

By re-interpreting the scientific pluralism discourse for science education, the present study is primarily expected to provide a ground for further discussion on the scientific

practice and pluralism issue in science education. In addition, analyses of historical cases regarding specific issues in physical concepts will by itself contribute to broadening pedagogical content knowledge, by exemplifying how educators can include scientific pluralism in science lessons and science curricula.

Do feminist critiques of science matter in science education?

Bansal, Deepika, University of Delhi, India
✉deebans.88@gmail.com

Feminists have articulated a variety of gender-based forms of oppression that have characterized modern science. As part of the 'liberal' perspective, less numbers of women in scientific practice have been brought to attention of the academia, governments and general public in most societies. This strand of feminist critique aims to find those women in history whose contributions to science were forgotten. It further provides a historical and sociological explanation of the systematic bias that prevented women from becoming an integral part of the scientific endeavour. But liberal feminist critiques of science take no issue with science as-is/was. The proponents of such a view believe that if more women could be encouraged to take up scientific careers, the situation would improve and justice would get served. On the other hand, the 'radical' critics of modern science accuse it of contributing to the creation and strengthening of gender inequalities historically. They assert that women and gender are routinely marginalized as subjects of scientific inquiry, or are treated in ways that reproduce gender-normative stereotypes, and then these 'scientific' stereotypes are used to rationalize social roles and institutions that feminists often call into question. Others challenge the soundness of scientific knowledge by exposing how gender ideologies of scientists creep into different stages of their rational, objective scientific work--from selecting a particular portion of reality to study, to describing it in certain terms, to framing testable hypotheses, and to describing the evidence called on to support a particular hypothesis. They go on to argue that the language of modern scientific project is steeped in sexual metaphors which are heavily biased in favour of all things male. These feminists criticize current formulations of objectivity, rationality and value-neutrality—the hallmarks of science—as highly gendered and, thus, heavily skewed.

From science education point of view, the liberal strand is amenable to direct action in the form of various programs, policies and pedagogic practices that may help redress the number gap. But the radical strand does not allow an easy drawing of educational implications. But I argue that this observation implies two things. One, not all history and philosophy of science research has direct pedagogical application and, two, even this kind of scholarly work can contribute to a science learning that is valuable from the social justice point of view.

▪ ORAL PRESENTATIONS - 2A 15:00-16:30 / Dec. 16, 2016 / Rm 203

What do science and math teachers think how they think?

Baykal, Ali, Bahcesehir University, Turkey
✉abaykal@boun.edu.tr

This study is based upon two axioms: First process skills must be the factors to determine the ends and means of teaching science and mathematics. Evidently there cannot be a mental skill free of content, but the subject matter matters to the extent that catalyzes the incubation of discovery and inventive drills and practices. It is not merely the substance but primarily the essence of science and math education what must be transferable to other domains of life. Second teacher is still the one responsible and eligible to design, implement, control and change the other constituents of instructional system. Within this framework the purpose of this study is to compare and contrast the selected "personal" tendencies of science and math teachers with teachers in other areas. These personal tendencies are Activeness, Sociability, Objectivity, Optimism, Originality, Intuition, Inquisition and Congruence. These attitudinal constructs have been inspired from the essays and articles written by Eysenck, Goldberg, Guilford, De Bono, Sternberg, Gardner and many others. Ten items for each construct have been written by the author. Preoperative construct validity of the subscales have been ensured with a specific unconventional technique. Judgements and evaluations 49 prominent experts were collected, and corrections were made accordingly. Participants are required to express their self -judgments on a nine point Likert scale questionnaire. 1 indicates "complete disagreement" and 9 specifies "perfect agreement" about how the given item characterize the tendency of respondent. The questionnaire is administered on-line. Items are randomly sequenced for each participant and only one item has been displayed on the screen independent from the others. Avoidance or omission of response is not allowed for any item. There is no chance for return and change the response after the final choice. There was no time restriction item wise, but two hours is given for the completion of the total test. 2018 teachers who applied for employment in a private K-12 school participated in the study. Participation was obligatory. Candidates had been informed before that their personal responses to the items might be reviewed in the interview to be held later.

Statistical analyses yielded positive results, Alpha reliability coefficients were found to be higher than satisfactory in each sub-scale. Non-parametric Friedman two way analysis of variance on the sub-scale scores showed that there is a significant pattern of attitudinal constructs. Teachers declared to have been Intuitive in the first place. The rank order of the tendencies are found to be as follows: Intuitiveness, Congruence, Originality, Inquiry, Optimism, Objectivity, Sociability and Activeness. Among the total 2018 participants 1361 of them are science and math teachers from various branches at various grade levels. They displayed a very similar tendency pattern.

Results indicate that the science and math teachers are not so much reflective practitioners as can be expected. There are some plausible explanations of this fact, but also there are some suggestions or pre-service and in service education of science and math teachers.

Dilemma of teaching science in Pakistan at primary school level: Problems and prospects

Khatoon, Sufiana, National University of Modern Languages, Pakistan
Gulnaz, Rani , Government Polytechnic Institute for Women H-8/1,Pakistan
✉skhatoon@numl.edu.pk

The present paper investigates dilemma of science teaching at primary school level. The research was carried out in Pakistani context. Generally, in Pakistan at primary level, teachers with diverse background of qualifications teach science through textbook teaching method. Previous

researches prove that teachers' background qualification and teaching method may effect on students 'motivation for learning of science concepts and in developing their attitudes towards science'. The major objectives of the study are: to assess background qualifications of teachers who are teaching science at primary school level; to determine teachers' attitude towards teaching of science; to assess primary school teachers' practices for teaching of science. The data for the study was collected through structured interviews with 20 female primary school teachers who were teaching grade four students in under developed area of Punjab, Pakistan. The collected data were collected through taking notes. From notes codes were generated and then these codes were organized and themes were generated. Major findings emerged from the data were: primary school teachers were using lesson planning, they make no discrimination between teaching science and other subjects; teachers who were teaching science did not have science background qualification; they were not familiar with new ways of teaching science, developing students' observation abilities and attitude toward were not focused in teaching. Generally, Students lack motivation for learning science and their capabilities of observation were not developed neither science teaching was connected to real life scenarios for creating relevancy of learn concepts, and it did lack practical activities/ hands on and peer learning experiences to generate knowledge. Textbook teaching method was the only method used for teaching. Memorization of conceptual knowledge is encouraged and is the only criteria for assessment in examination for scoring good marks. To fulfill gaps, it is suggested that provision science teachers with minimum bachelor in science education and science laboratories can be conducive for achieving the genuine objectives of science teaching at primary school level and can enhance quality of science teaching and learning. Present research has implications for policy makers, planners and curriculum developers and teacher trainers to take required steps in order to fulfill the gaps.

Keywords: Teaching science, primary level, teachers, attitude, practices, problems, back ground qualification

New directions for development of and research on computer-based scaffolding emanating from meta-analyses of scaffolding

Belland, Brian, Utah State University, USA
Walker, Andrew, Utah State University, USA
Kim, Nam Ju, Utah State University, USA
Piland, Jacob, Utah State University, USA
✉*brian.belland@usu.edu*

Computer-based scaffolding is support that helps students engage in activities (e.g., problem solving) that are beyond their unassisted capabilities. As such, it is an essential tool to facilitate the use of problem-centered instructional models, which have become very prominent in the USA and other parts of the world due to the need to help students develop problem solving skills in concert with content knowledge. Computer-based scaffolding has been grounded in many theoretical frameworks, including cultural historical activity theory, adaptive control of thought-rational, and knowledge integration, and employs many strategies, including expert modeling, question prompts, and visualization, and serves to both structure and problematize the learning task, and enhance motivation. Furthermore, the contexts in which scaffolding is used include diverse education levels (K-12, college, graduate, and adult), problem-centered instructional models (problem-based learning, project-based learning, inquiry-based learning, and case-based learning), and disciplines (humanities, social sciences, and STEM). Much research has been conducted on scaffolding, but the sheer number of studies and different scaffolding variants and contexts of use makes it hard to make evidence-based conclusions about scaffolding. The current authors have engaged in meta-analysis efforts to synthesize the between-group (traditional meta-analysis from frequentist perspective) and within group effects (Bayesian network meta-analysis) of computer-based scaffolding in STEM education at the K-Adult levels. Findings include that computer-based scaffolding is highly effective, leading to a between group effect of $g = 0.46$ that is robust to assessment levels (concept, principles, and application). Networks of within group effects are also strong and at least $g = 0.7$ across assessment levels. The two meta-analyses indicate that customizing scaffolding (i.e., fading, adding, and fading/adding) does not help learning, and may actually harm within group effects. Furthermore, scaffolding's between subject and within subject effects are strongest at the graduate and university-level, respectively, which is interesting as these are the populations farthest from the original population for whom scaffolding was first conceptualized - toddlers. Results are discussed in light of the literature, and future directions for scaffolding research are proposed.

▪ ORAL PRESENTATIONS - 2B

15:00-16:30 / Dec. 16, 2016 / Rm 204

Beyond classroom boundaries, Unlocking science learning among indigenous learners in Malaysia

Wong, Cindy Chyee Chen, National University of Malaysia, Malaysia
Osman, Kamisah , National University of Malaysia, Malaysia
✉*chyeechen@yahoo.com*

In the 21st century that emphasized on knowledge-based society, the demand for large scale of human capital workforce which based on scientific knowledge is rising especially in science field. Therefore, indigenous learners in Malaysia need to upgrade themselves through school education in order to prepare for future needs. Meaningful learning where learning process takes place in a conducive and simulative learning environment can lead to better science achievement and self-concept. Hence, this study aimed to determine the effects of the Learning Outside the Classroom (LOC) science module toward enhancing science achievement and self-concept among indigenous learners. In this study, self-concept refers to evaluative appraisal of oneself in academic and non-academic aspects. For that, quasi-experimental approach with pre-test post-test, nonequivalent control group research design was implemented. A total of some 73 primary school indigenous learners were involved in the study. The experimental group (n=38) used LOC module while the control group (n=35) used inquiry method in teaching science. Science achievement evaluates using Science Achievement Test (SAT) whereas self-concept evaluates using Self Concept Questionnaire (SCQ). Data obtained from SAT and SCQ were analyzed using Independent-sample T-test and MANOVA repeated measures. Results showed non-significant increase in the mean scores of SAT in the experimental group. As for self-concept, there was a significant main effect of group but no significant main effect of time and interaction effect between time and groups. Implications from this study were especially toward teaching and learning (T&L) practices and indigenous learners where more systematic T&L and fun learning that lead to active participation among learners can be applied. These ultimately enlightened the indigenous learners about the importance of learning science in school.

Understanding of the interest in science learning based on John Dewey's concept of interest

Mun, Kongju, Ewha Womans University, Korea
✉*munkongju@gmail.com*

The purpose of this study is to understand the concept of 'interest' and to search implication and effects of John Dewey's concept of 'interest' in science education researches. Although interest is importance concept in Dewey's education theory, it seemed to be misunderstanded and rather than to be interpreted reasonably in science educators. Dewey's concept of interest emphasizes the psychological desire and need. This emphasis can be matched with current goal of science which focus on develop students' character and value though science education. Many researchers misunderstand Dewey's concept of interest ignore the value of the knowledge based on Peters's criticism of Dewey's theory of interest. However, his criticism accounts on dualistic view. In this study, I took the unbiased viewpoint of Dewey's concept of interest and his educational theory for understanding the concept of interest in science learning. I reviewed researches which examined interest in science learning context. Many researchers examined interest in science learning without defining of its' meaning and not interpret it deeply. Additionally, there is lack of clear identification among similar psychological aspects such as motivation, attitude and interest in science learning. I suggested the theoretical framework of interest in science learning based on review of previous researches wearing lens of Dewey's concept of interest.

Use of robotics in preparing teachers to teach science

Kim, Chanmin, University of Georgia, USA
Yuan, Jiangmei, University of Georgia, USA
Vasconcelos, Lucas, University of Georgia, USA
Hill, Roger. B, University of Georgia, USA
✉*chanmin@uga.edu*

This presentation reports a mixed methods study in which robotics was used in early childhood education teacher preparation. The content analysis of the study was on these preservice teachers' lesson subjects, topics, grade-levels, instructional approaches including robotics integration methods, and affordances utilized. The pre- and post-surveys on science interest and STEM enjoyment were used to examine these preservice teachers' changes after their engagement in a robotics learning module. Findings and implications are discussed during the presentation and the full paper.

▪ ORAL PRESENTATIONS - 3A

09:00-10:30 / Dec. 17, 2016 / Rm 203

Science education at crossroads: Socio-scientific issues and education

Park, Jee-Young, Seoul National University, Korea
Ma, Eunjeong, Pohang University of Science and Technology, Korea
✉*eunjma@gmail.com*

This paper discusses pedagogical issues and challenges in science and technology education. A departure point for current research is grounded on the pedagogical belief that the goal of science education is to go beyond delivering technical information and skills and is to cultivate globally competent and socially conscious scientists. Global competence can be defined as the ability to work effectively with people across the disciplinary boundaries, national and cultural borders. As science and technology get ever more converged, we tend to treat science loosely rather than fixating on the understanding based on disciplinary boundaries. Drawing on literature review and pedagogical experience, the researchers wish to contribute to and shed some light on continuing dialogue on the intersections between science education and socio-scientific issues.

In this paper, two researchers, who have been deeply engaged with science and technology education at the university level for multiple years, first present the historical and contextual needs to incorporate socio-scientific dimensions into science and technology education. At this stage identify and discuss three strands of socio-scientific issues in science education and re-evaluate/reflect them in pedagogical practice: motivational desire, convergent science and technology, global challenges and social responsibility in relation to problem setting and solving. Conscious of these strands, two researchers independently have tried to incorporate social and ethical issues into science and technology education at the university levels. In the second part of the paper, we brief challenges and issues encountered and experienced in convergent education. We have found that it is painfully rewarding experience to infuse technical information with societal and cultural issues of science situated in a broader context. The challenges we have encountered are as follows, for instance. On the one hand, the depth of knowledge is needed to become a competent scientist, which tends to dissociate technical knowledge from non-technical issues such as social and ethical issues. On the other hand, to become a socially and globally responsible leader, a student needs to understand and attain scientific knowledge in relation to society or in association with society. And yet, we have begun to notice that students think and speak socio-technical issues in science and technology at the least. To conclude, based on our experiential practice and knowledge, we would like to share some challenges and issues to be solved and then cautiously propose some ways to strengthen the infusion between science education and social, humanistic, and artistic issues.

Will science solve all our genuine problems?

Hammann, Marcus, Westfälische Wilhelms Universität Münster, Germany
Konnemann, Christiane, Westfälische Wilhelms-Universität Münster, Germany
Asshoff, Roman, Westfälische Wilhelms Universität Münster, Germany
✉*hammann.m@uni-muenster.de*

An empirical investigation of scientistic beliefs among German High school students

Despite its significance within the philosophy of science, scientism - understood as the belief that science alone can and will solve all of our genuine problems - is a topic treated only tangentially in the science education literature (Hammann et al., under review). Within the philosophical literature, different categories of scientistic beliefs have been described (Stenmark, 2001). In the present study we use semi-structured interviews to gain information on high school students' agreement with various categories of scientistic beliefs (comprehensive, existential, axiological, epistemic scientism) and exploring scientistic beliefs within three contexts for potential scientistic misunderstandings (1. evolution and creation, 2. evolution of religion, 3. evolution of morality). Participants (n = 7) were selected based on their responses to a quantitative survey (Konnemann et al., 2016) according to which five students were characterized by a scientistic attitude profile and two students by a distinctly non-scientistic profile. Using qualitative content analysis we found that all students regarded science as one of the most important aspects of human knowledge and culture. However, while all of the students with a scientistic attitude profile showed agreement with one or more categories of scientistic beliefs, the non-scientistic students did not show any agreement. Implications for educational approaches tackling scientistic beliefs will be discussed.

Theoretical investigation on the merit of conceptual blending in comparison with metaphor and analogy in science education

Cheong, Yong Wook, Seoul National University, Korea
✉*zimusa@snu.ac.kr*

Framework of conceptual blending was suggested as an alternative view of conceptual metaphor in the field of cognitive linguistics. The frame has become an influential alternative of the conceptual metaphor (or analogy) in various fields. However, only few studies have investigated the possibility of the frame in the context of science education or philosophy of science although original advocators of the frame initially mentioned that the conceptual blending could be crucial in the discovery of new scientific knowledges. In the recognition of problem, this study theoretically investigated the possible merit of the frame by case analysis on several scientific concepts such as particulate view of matter and wave-particle duality. For the purpose, we briefly discuss how the notion of conceptual blending differs from the notion of conceptual metaphor or analogy. Then we examine the merit of conceptual blending view by analyzing contents of science textbooks on static electricity, ideal gas law, and wave-particle duality. We found that the contents of the textbooks could be better understood within the frame of conceptual blending than the view of metaphor and analogy. Thus, it could be possible that conceptual blending might be a better framework for the educational researches concerning the analyzed contents beyond conceptual metaphor or analogy. This imply that it would be necessary that science education researchers investigate further the pro and con of conceptual blending as an alternative view of metaphor and analogy.

Keywords: conceptual blending, conceptual metaphor, analogy, particulate view of matter, wave particle duality

▪ ORAL PRESENTATIONS – 3B

09:00-10:30 / Dec. 17, 2016 / Rm 204

Effect of science drama program on creativity and character education for science gifted

Bae, Junghee, Pusan National University, Korea
✉*bjh340@hanmail.net*

This research intends to examine the effect of science drama program on creativity and character education for science gifted students. Research subject was sampled from 151 new entrants to science gifted education center affiliated with university in the year 2014. 65 students among 151 new entrants who participated in science drama program were selected as research subjects due to their completion of survey instruments before and after science drama program. Before science drama, students responded with high percentages of reasons for preference to scientist's in creativity-cognitive domains, in particular, scientists' originality and the student's own intelligent curiosity. After science drama, in comparison before, the science gifted students still prefer to creativity-cognitive, scientists' originality of 30% in highest percentage. Also, communication ability increased dramatically from 1.5% to 15.4%. For non-cognitive, percentages decreased from 33% t0 25%. However, motivation increased from 7% to 9%. For character, percentages were not much changed with 12% for before and after.

Regarding overall reflections, For creativity-cognitive, acquisition of knowledge showed 30% as highest percentage while scientists' originality decreased from 30% to 3%. For creativity - non cognitive, interest (9%) and confidence (8%) increased. The percentages for character - personal and social increased from 12% to 43%. For character - personal, sympathy, care, responsibility, and diligence increased distinctly. For character - social, percentage for teamwork increased from 1% to 25%. It was recommended that science program integrated with arts may be effective for developing creativity and character.

Revisit Galileo and science in his term

Park, Eunjung, Sookmyung Women's University, Korea
✉*ohiopark@gmail.com*

In the history of science, Galileo is very a famous scientist who has been at the center of controversy and caused a revolutionary change. However, for many students, he is a familiar person they've seen from their childhood along with the phrase "And yet it moves (E pur si muove)." Despite he did not actually say so. Today, we are able to see his name in various fields covering mathematics, science, music, religion, art, etc. Although he worked as a mathematician in Italy at his time (1562-1642), documents show that he wanted to be named or written as a philosopher as much as a mathematician. Assuming it as science in a comprehensive context, this study investigated the meaning of what he said as "philosopher or philosophy". To the end, his books (Sidereus Nuncius, the assayer, two new sciences, and dialogue concerning the two chief world systems) and letters (letters to the Grand Duchess Christina, sunspot letters, letters to Benedetto Castelli) were examined in detail. Analysis of the given data informs what science means to Galileo and how he balances science and beliefs. Elements revealed in Galileo's work show the essence of science nature and advanced views albeit written in 16 centuries. In this respect, educational implications and applicability of the data will be further discussed.

Francis Crick and his influence on genetic code research in China

Sun, Yongping, Inner Mongolia Normal University, China
✉*gracemmercy@126.com*

The research aims to reveal the scientific life of Francis Crick who was the co-discover of DNA structure. Based on the literature research and concept analysis, it mainly shows that what the scientific life of Francis Crick is like, the Crick's contribution to genetic code research more completely through consulting a greater and wider range of materials and interviewing people who knew him and how his scientific thinking influenced the genetic code research, especially Mutational Deterioration Theory proposed by Luo liaofu who is a Chinese scholar and whose work is well known internationally. By comparison, the differences and common grounds between Crick and Luo in terms of genetic code are studied clearly.

▪ ORAL PRESENTATIONS - 4A

15:00-17:00 / Dec. 17, 2016 / Rm 203

The effect of background knowledge and metaphysical belief on interpreting quantitative data

Park, Jongwon, Chonnam National University, Korea
Lee, Insun, Chungbuk National University, Korea
Kim, Ikgyun, Chungbuk National University, Korea
✉*jwpark94@jnu.ac.kr*

This study started to understand the detailed processes and features of students' interpretation of quantitative data. In the previous study (Kim et al., 2016), many students, when interpreting the quantitative data, drew various complex relationships between variables because of erroneous data generated in the process of obtaining data. However, many physicists have emphasized on inferring and extracting fundamental and simple relationship from the complex nature. Therefore, this study was to investigate the reasons why they drew so complex relationships instead of simple ones including appropriate treatments and interpretations of errors. To do this, 16 university students in the college of education participated and were asked to answer the questions about metaphysical belief to explore the effect of metaphysical belief on data interpretation. The questions were about whether it is important to find out detailed and accurate information even though it is complex, or simple laws wherever possible because fundamental key is important. And subjects were divided into two groups; one group received data, including the brief experimental information about what the data was, but the other group received only measured data without any information about the experimental context and what variables were. This was to check the effect of background knowledge related to the data on interpretation of the data. As a result, it was found that two factors affected the data interpretation. In the presentation, researchers will talk about the characteristics and meanings of this result compared to the historical instances in science.

College students' understanding about the metaphysical meaning of scientific concepts/phenomena and their perception of the importance of it in their everyday life and teaching science

Kim, Min Kyoung, Chonnam National University, Korea
Park, Jongwon, Chonnam National University, Korea
✉*jwpark94@jnu.ac.kr*

According to Kuhn, paradigm consists of five components; core laws and assumptions, standard application of core laws, experiments connecting core laws with real world, general and metaphysical principles, and general methodological prescriptions (Charlmers, 1986, p. 91). This means that science students need to think about and lean metaphysical meanings involved in basic scientific concepts and phenomena. Moreover, it has been pointed that many students think that physics is not related to their everyday life because physics describes and explains ideal and abstract world. However, metaphysical meaning of physics can give us a basic view/perspective of or realization about everyday life as well as nature. For example, the metaphysical meaning of 'Newton's 3rd law' may be described as 'Do as you would be done by' based on students' levels. Therefore, this study starts to introduce metaphysical meaning to students to help them realize that physics is closely related to their everyday life. To do this, at first, we extracted and categorized metaphysical meanings of physics concepts or phenomena learned in middle school science. And, secondly, students at the college of education, because they will teach physics in the future as a teacher, were asked to write metaphysical meaning of physics concepts or phenomena involved in the middle school science textbook. Finally, they answered the questions about the importance of metaphysical meaning in their everyday life, and about the need to teach metaphysical meaning in middle school science class. As a result, ten metaphysical meanings could be extracted from two units in the 7th grade science textbook. And it was found that many college students could draw metaphysical meanings from the suggested physics concepts and phenomena. Examining their answers according to common features of metaphysical meaning, the meanings could be categorized to various big meanings, such as cooperation, conservation, change, effort, choice, balance, and so on. However, college students answered that metaphysical meaning is slightly important in their everyday life and agreed slightly that metaphysical meanings needs to be taught in middle school. In this presentation, we will talk about the reasons why agreement about the importance of metaphysical meanings is positive but not so strong. And we will suggest teaching plans for introducing metaphysical meaning in middle school science class.

A simple experiment and embarrassed instructions: Boyle's quantitative experiment, explanation and mechanical philosophy

Gim, Jinyeong, Seoul National University, Korea
✉*jinyeong.gim@gmail.com*

Boyle's Law is the only scientific law which South Korean students in the elementary school learn. The design for students to learn this law is so simple as follows: students fill in a little air in a syringe, close entrance of it with a hand, and press a piston of it with small and strong forces respectively. Then, they observe states of volume of the air in the syringe. Approximately, nevertheless, only one third students correctly conclude the relation between pressure and volume of the air. The aim of this paper is to elucidate the causes of this unexpected result. By focusing on how students understand instructions in a textbook, I point out three problems. First, textbook authors overemphasize too qualitative experiment to hinder students from learning Boyle's law quantitatively. Second, a usage of the term explanation in the textbook makes students misunderstand their activity. Third, it is unsuitable to introduce the term gas particle with which students are forced to explain an elastic property of the air. Rather than showing a concrete alternative, I will just illuminate Boyle's main ideas to emphasize the significance of quantitative experiment and the nature of explanation on the basis of his mechanical philosophy.

The historical perspectives of species concept development is the basement of modified mechanism for biological species concept

Lai, Bo-Chi, Da-Yeh University, Taiwan
✉*biophilia.lai@gmail.com*

Regardless of philosophical arguments about "is species real?", in biological concepts, species is so real and fundamental, being the basic unit for systematic classifying organisms by taxonomists. The species concept is the important implication to approach the phenomena of organisms. In the history of biological thoughts, there are dozens species concepts been proposed, and the biological species concept (BSC) proposed by Ernst Mayr in 1949 has been one of the most popular species concept for several decades. The BSC suggested reproductive mechanism to identify individuals as species. The reproduction between individuals can describe the entities of spatiotemporally localized relationship in a species and cohesive at any one time. Even though Mayr has not only modified the BSC to more molecular evolutionary and phylogenetic concerns but also defended that the BSC is the only concept can illustrate the meanings of species referring to both species as taxa and the category species, the most critical point of BSC admitted by Mayr is that the BSC obviously does not account for asexually reproducing organisms. The weakness of BSC can be considered as the reproductive isolation not being consummate because the "mechanism" of postzygotic barriers dose demonstrate the cell and gene level, the major issues for BSC applying to asexually reproducing organisms. Until today, BSC is still entangled with several major species concepts without agreements.

In this article, I will interpret the key points argued among the major species concepts by mainly referring publications The Species Problem (1957), Species Concepts and Phylogenetic Theory (2000) and Species: A History of the Idea (2009), former two proposing and debating biological idea and the later surveying historical context. The implication of Mayr's

species concept is "biological", different from others, because the concept emphasizes the reproductive success in a species rather than methodological analyses to suggest the species. Nevertheless, how to response other idea of species concepts is necessary for proposing my modified mechanism of biological species concept, the Neo-Biological Species Concept (Neo-BSC). According to the rising of molecular biology in past few decades, the construction of species concepts have been influenced strongly. I would like to illustrate my modified mechanism, named as communicative-isolation mechanism, based on the molecular theories of cellular communications, the models of signals and receptors between cells at the molecular level, to response the debates between BSC and modern phylogenetic theories of species concepts.

▪ ORAL PRESENTATIONS - 4B

15:00-17:00 / Dec. 17, 2016 / Rm 204

The development of an instrument for measuring the creative engineering problems solving propensity for STEAM

Kang, Ju-Won, Pusan National University, Korea
Nam, Younkyeong, Pusan National University, Korea
✉*ynam@pusan.ac.kr*

This study is to develop a valid and reliable instrument for measuring students' creative engineering problem solving propensity. The creative engineering problem solving is operationally defined in this study as a creative problem solving skill in an engineering context. To develop the instrument, first we define seven common constructs between engineering problem solving skill and creative problem solving skill through an intensive literature review; motivation, context, personal character, engineering design, engienering habits of mind, understandings of engineering and engineers, communication skill, and collaboration skill. Based on the seven constructs and the face validity test conducted by two in-service science teachers and 4 experts in science education research, 40 preliminary items were developed. Then the preliminary instrument was implemented in a science gifted highschool to measure the reliability of the instrument. From the 40 items, 34 items were selected through the initial reliability test by Cronbach's α (>.75). Finally through the three times of factor analysis process, 28 items in five construct categories were selected; motivation (3 items), engineering design (6 items), engienering habits of mind (9 items), understandings of engineering and engineers (4 items), communication and collaboration skill (6 items). The factor analysis result showed that the reliability of each construct category was between .733 to .892., meaning that the instrument is reliable in terms of the higher structural validity (each item is categorized in an appropriate construct category). We expect that the creative engineering problem solving propensity instrument developed in this study can be used in various contexts for STEAM education research as a reliable and valid instrument

The development and effect of learner-centered interactive STEAM program based on movie contents "THE MARTIAN"

Choi, Jin-young, DaeJeon Je-il High School, Korea
Choi, Su-young, Hannam University, Korea
Shin, Hyun-sook, DaeJeon Je-il High School, Korea
Kim, Chun-bong, DaeJeon Je-il High School, Korea
Lee, Young-bae, DaeJeon Je-il High School, Korea
Kim, Jin-young, DaeJeon Je-il High School, Korea
Eom, Tae-hyeon, DaeJeon Je-il High School, Korea
Yoon, Ma-byong, Jeonju University, Korea
✉*dsits@naver.com*

The purpose of this study was to develop a learner-centered, interactive STEM program based on movie contents and to verify the effectiveness of the class. In this study, movie contents of The Martian were utilized to increase learners' engagement and interest. By referring the standards of achievement of the four subjects (science, technology/home economics, mathematics, and Korean), four activity-based learning objectives or topics were developed from the survival situations in The Martian. Learning subjects are to encourage students to actively accomplish missions in each subject-specific class. This study was also designed to facilitate concept learning and its application. The main subject is science, and the completely developed program was applied to 8 classrooms in a grade level at a school.
To verify the effectiveness of the program, the Chi-Square test for homogeneity was conducted through a group comparison of the pretest scores (matched pair T-test). As a result, the four groups (immersive, bored, ambitious, and observant) had significant differences between the groups in scientific attitudes ($F=9.225$, $p<.001$) and attitudes toward science ($F=14.872$, $p<.001$). Next, the pretest result was utilized as a covariate by applying the pretest-posttest designs (covariance analysis), and the adjusted posttest scores were used to verify the effectiveness of the program. As a result of analysis, The learner-centered, interactive STEAM program based on The Martian contents showed statistically significant positive differences in attitudes toward science ($F=133.204$, $p<.005$), scientific attitude

(F=10.225, p<.001), and each subcategories of all four groups. Therefore, the learner-centered, interactive STEAM program designed for interdisciplinary studies is expected to make a significant difference in both aspects of theory and practice, such as a scientific attitude as a learner's affective domain and an attitude toward science that can be applied to real-life situations.

The systems thinking based STEAM program topic -Making my creative water clock

Kim, Hyung-Uk, Im Dong Elementary School, Korea
✉*hhwwkk322@naver.com*

Recently, a lot of development or studies of a STEAM program have been conducted; however, there are not enough concrete efforts and studies of the development of a STEAM program based on systems thinking through which one recognizes a whole, instead of linear relationships and understand the cyclical causalities and dynamic relations among the parts included in the whole, continuously. This study aims to develop a STEAM program based on systems thinking, apply it to elementary school students, improve their systems thinking, a higher-dimensional thinking skill and analyze their attitudes towards STEAM and other educational effects.

For the program development, this study reviewed literature, analyzed the preceding studies of STEAM and systems thinking and developed a systems thinking-based STEAM program with the topic, "Water Clock (Clespsydra)" which is familiar to students. The developed program went through the primary modification and supplementation of a group of experts consisting of professors, graduate students and in-service teachers with long work experience, and after preliminary application to 10 students enrolled in a school in A. City, a small city, it was completed as a program consisting of six class hours, finally. The subjects of the study were 45 fifth- and sixth-grade students in A. City and C. County, and as a test of their systems thinking and attitudes towards STEAM before and after the program application, a single-group pretest-posttest paired sample t-test was conducted. The results of the study are summarized as follows:

First, this study developed a STEAM program with the topic, "Water Clock" based on systems thinking, using ADBAS Model (Park Byeong-yeol, 2013). The program was developed to improve students' systems thinking which has been considered to be somewhat difficult to apply to elementary school students till now, and it has a significance that it is a topic that can arouse students' interest and develop their circular thinking and ability to understand causalities. Second, as a result of a verification of the improvement of their systems thinking and their attitudes towards STEAM through systems thinking-based STEAM program developed for fifth- and sixth-grade students, it was found that they showed a little more concrete and developed thinking, including analyzing the relationships among words, drawing causality maps and drawing pictures in systems thinking. This study drew statistically significant results from the affective domain, including attitudes towards STEAM and satisfaction with it.

In conclusion, the systems thinking based STEAM program with the topic, "Water Clock" developed in this study is appropriate for the cultivation of systems thinking, an advanced thinking skill and has an important implication that it measures elementary school students' systems thinking skill. It would be necessary to put vitality into the cultivation of new scientific thinking skills, actively utilizing systems thinking in developing a STEAM program for elementary school students in the future. Also, it would be necessary to make an effort to generalize it for easy utilization by active propagation to the field.

Enhancing pre-service science teachers' epistemic understanding of arguments through a science inquiry activity

Chen, Ying-Chih, Arizona State University, USA
Nam, Younkyeong, Pusan National University, Korea
✉*ynam@pusan.ac.kr*

Socio-scientific issue (SSI) impacts pre-service teachers' argumentative practice in two ways: social negotiation and epistemic understanding of arguments. Twenty pre-service science teachers participated in this study as a part of their science methods class. Small group discussions, while participating in an SSI debate, before and after engaging in a science inquiry activity, were collected as a main data source. The data were analyzed by an analytic framework adapted from both Toulmin's (1958) model of argument structure and Walton's (1996) reasoning scheme.

The results indicate that the use of a science inquiry activity during SSI debate not only affects the teachers' social negotiation patterns, but also enhances their epistemic understanding. This study suggests that incorporating a science inquiry practice into an SSI debate has the potential to improve students' disciplinary engagement and the quality of their argumentative practice.

▪ STEAM Symposium - 4C 15:00-17:00 / Dec. 17, 2016 / Rm 209

STEAM education in Korea

Park, Hyunju, Chosun University, Korea
Baek, Yoon Su, Yonsei University, Korea
Kim, Youngmin, Pusan National University, Korea
✉*minkiyo@pusan.ac.kr*

STEAM education in Korea was stared from 'the research about direction of STEAM education in Korea', which Back, el al (2012) conducted during 2011-2012 by KOFAC research grant. Ministry of Education and KOFAC announced the direction and method about STEAM education in Korea based on the research results including Back, et al (2012). In the research 4C-STEAM education was proposed. 4C-STEAM education refers the STEAM education focused on Convergence of knowledge, Creativity, Communication, and Caring, which include creative design and emotional experience.

At the same time KOFAC supported the researches for development of curriculum including STEAM education subjects for the pre-service teachers of primary and secondary school. And KOFAC and MOE hold STEAM education conference annually since 2012. In the conference many of policy, research results, and action programs related to STEAM education have been presented. In addition KOFAC has supported 10 to 20 STEAM education research and practice teams consisted of primary and secondary teacher, and supported around 20 leading primary and secondary schools for STEAM education practice nation widely. For school STEAM education, two Science and Arts High Schools educating the gifted in science will be established in 2015 and in 2016. In the formal curriculum, integrated STEAM activities are given to the students in a few requirement subjects. (KEDI, 2014) In this year, 2014, 'Sejong Science and Arts Gifted High School' was established, and next year, 2015, another Science and Arts Gifted High School will be established in Korea. In the curriculum for the students of the two schools, five subjects that are consisted of integrated STEAM activities are included as elective subjects.(Kim, et al, 2014)

STEM education in Canada: Some initiatives and challenges

Kim, Mijung, University of Alberta, Canada
✉*mijung@ualberta.ca*

Canada has experienced several challenges in STEM education. Science, Technology and Innovation Council in Canada reports Canada's lagging performance on business innovation and the increasing gap between Canada and the world's top performers in economy development and STEM related industries. Another challenge is students' interests in science and science-related careers decline from early ages in elementary schools and the numbers of students entering STEM related fields in post secondary education also decrease. To alleviate these challenges and concerns in STEM education and economic development, there have been several initiatives to promote STEM learning among school children and college students. Yet, STEM initiatives have mainly been through outreach programs run by universities or NGOs in collaboration with private companies or industrial findings such as WISE Atlantic program in Nova Scotia or Actua across Canada. These outreach programs encounter sustainability and equity issues with limited funding and limited space and opportunities for students. Recently, there have been efforts to embed STEM approach in school education systems through developing teacher knowledge and skills of STEM. STEM researchers and educators account for the need of STEM practice in classrooms and develop teacher education program to advocate STEM approach in school curriculum. STEM educators in Canada also challenge the current focus of economy-oriented STEM education as neoliberal technical approach to educating next generations. They emphasize the importance of collaborative knowledge building, critical thinking and creative problem solving for sustainable future society as the core elements of STEM education. This group of educators also emphasizes a unique challenge of STEM education in Canada, that is, the gap between aboriginal and non-aboriginal students' performance in science and math. This notion also relates to an increasing gap of STEM, labour markets, and economic stability in life for aboriginal students. How to embrace and integrate the worldview of western science and aboriginal knowledge of science in harmony has been questioned to contextualize local knowledge in STEM education in Canadian classrooms.

Arts integrated STEM education in Australia

Chu, Hye-Eun, Macquarie University, Australia
✉*hyeeun.chu@gmail.com*

The aim of this paper is to provide an overview of the political, economic, and educational environment in Australia that is relevant to the promotion of STEM and STEAM education in Australian schools. There have been concerns at the highest level of government and the business community about Australia's future competitiveness in a world heavily reliant on keeping up with advancements in science and technology. There is a widely acknowledged realisation that the key to maintaining the nation's competitiveness is to sustain a high level of STEM literacy in its population. This paper will present evidence that appears to justify the concerns about a possible inadequate level of STEM literacy in Australia: the declining performance of Australian students in international science tests compared to other developed countries. Measures are being taken by state education departments in Australia to implement STEM education with the aim of motivating more students to study the hard sciences at Year 12 and university. This paper will give a brief account of current developments in STEM education at the level of state education departments and school level. A contribution to the national effort to implement and improve the STEM teaching approach in primary schools is an ongoing arts integrated STEM (STEAM) research project which is a collaborative project involving academics from two Korean universities. This paper will end with a brief report of the aims and methodology of this project.

M-STEAM program based on modeling management

Kim, Seongman, Sasang High School, Korea
Lee, Hyeounrok, Sasang High School, Korea
✉*hdoore@hanmail.net*

We propose STEAM education in secondary level based on mathematical modeling teaching called M-STEAM. Though variety of teaching materials for STEAM education in elementary level are developed considerably small number of STEAM programs for secondary schools are ineligible. Even worse the only few STEAM programs for high school are mainly for after school program or not much curriculum based. Therefore it is hard to find STEAM program acceptable for regular class in regard of national curriculum. Math and science teachers of STEAM research education group worked pilot study for analyzing interconnected subjects in math and physics and articulate lesson plan based on math and science national curriculum standard. The developed M-STEAM program manages mathematical modeling in data logging physics lab along with whiteboard discussion. Though the suggested lesson topics are normal in ordinary science lab such as motion of basketball and pendulum bob, the M-STEAM class are took advantage of in data logging using motion sensors and math software for modeling tool in facilitating Technology and Engineering of the STEAM environment. Students showed positive response in learning motivation of mathematical value, interest, and understanding of physics concepts after modeling based math-science integrated STEAM program.

Project for globalization of STEAM education in Korea

Kim, Youngmin, Pusan National University, Korea
Baek, Yoon Su, Yonsei University, Korea
Park, Hyunju, Chosun University, Korea
Kwon, Hyuksoo, Kongju National University, Korea
✉*minkiyo@pusan.ac.kr*

The purposes of this project are to foster STEAM education capacity of Korea by comparing with and inducing strong points from other developed countries, to make a long term action plan for sharing STEM/STEAM education methods and programs and cooperating for the improving teaching learning methods and programs with other countries, and to propose ideas for further researches in globalization of STEAM education.

POSTER PRESENTATION

▪ POSTER PRESENTATION 1-13 17:00-18:00 / Dec. 16, 2016 / Conference Hall

A meta-analysis of inquiry-based instruction on student learning outcomes in Taiwan

Wang, Jing-Ru, National Pingtung University, Taiwan
✉jrwang1022@gmail.com

The aims of this study were to investigate the effects of inquiry teaching on elementary and middle graders' learning outcomes from the year 1997 to 2009 in Taiwan, as well as to explore the moderators that mediate the effectiveness of IBI on students' conceptual knowledge growth, scientific process skills and affective attitude attainments. Considering the problem space and the lack of existing published research on the topic in Taiwan, it was decided to use a meta-analysis approach in this research because it would generate summary findings of many empirical studies and general conclusions. The critical components of the design were acquisition of studies, criteria for selecting studies, coding of studies, and meta-analysis procedure. Of 367 studies comparing IBI with traditional instruction, 287 were independent effect sizes (some studies included more than one effect). An unexpected finding was that only a small number of studies were published in journals. Instead, the majority of studies were unpublished dissertations. These results revealed that although a large amount of studies were designed and conducted through an array of serious processes to investigate the effectiveness of IBI, the effectiveness of inquiry teaching remain invisible in Taiwan. Although the weighted mean effect size analyses attested to the greater positive benefits of IBI on students' learning outcomes compared to traditional teaching, content area and grade level were found to moderate the effects of inquiry-based instruction on learning outcomes. The evidence presented in this study justifies the continued use of inquiry teaching in the teaching of science.

Routes of secondary-school science textbooks from western countries to Korea

Kang, Eugene, Pusan National University, Korea
✉soc-none@hanmail.net

Many schools have since 1883 been founded by Koreans and foreigners to enlighten Korean pupils and enhance their abilities. According to official government documents, there were 2,237 schools including 1,282 private schools, 755 missionary schools, and 82 government schools in 1910. School founders and heads thought the most important knowledge from Western civilisation was science and technology. They tried to teach western science and technology with various materials.

After 1910 when Korea was forced to be Japanese colony, most curricula in Korean schools were controlled by the Japanese government. This is why only Japanese textbooks and materials for science education were adopted in schools after 1910. Before 1910, various sources were used in Korean schools. According to government documents for school textbooks, 138 science textbooks were approved by the Minister of Education from 1895 to 1915 (Park, et al., 1998).

Most schools adopted science textbooks in Korean or classical Chinese, while some missionary schools adopted science textbooks in English. Authors and editors of textbooks were Koreans, Japanese, Chinese, and western. 62 of 138 textbooks were published in Korean territory, and 38 authors were Korean. Science textbook writers were not specialists in science education (Park and Chung, 2000).

Japan was the most important country to influence Korean science education in the 19th and 20th centuries. Many authors of science textbooks studied in Japan. Previous research has shown what science textbooks were used in Korean schools and who wrote and published these in the late 19th and early 20th centuries. However, these studies just focused on Korean authors and Korean territory. Science textbooks written by Koreans in the 19th century had to be influenced by western knowledge. Only Japanese influence was clearly acknowledged.

There were three possible routes. One was from western countries via Japan, according to previous research. Another was be the direct route from western countries. Missionaries could play an important role in this enterprise. The third route was from western countries via China. Before the first Sino-Japanese war in 1894, Korea was strongly influenced by China. As Korean intellectuals were familiar with Chinese literature, they might read science books from China rather than other countries and were influenced before 1894.

Exploration about the relationship between science & engineering university students' the career choice factors and their prior experiences of science activities before college

Yoo, Jungsook, Ehwa Womans University, Korea
Rhee, Hyang-yon, Ehwa Womans University, Korea
✉jsyoo16@ewha.ac.kr

In this study, we investigated the level of science & engineering students' prior experiences of science activities and the factors which affected the students to have chosen their major before college, and we further explored the relationships between the factors. A total of 102 science (N=24; female=16, male=8) & engineering (N=77; female=37, male=40) college students (female=53, male=48) who were performing a science outreach program participated in the study. The survey consisted of 61 items under three main categories: 1) general background information, 2) the level of experiences in science activities during their elementary and secondary school years, and 3) the factors to have chosen their major in science and engineering before college.

Overall results showed that the level of students' science-related experiences in and out-of classroom were higher for female students than for male students (tin=-3.424, p<.001; tout=-4.371, p<.001) while the level of home-based experiences were not different by gender. These results indicate that our female participants were highly science-oriented students.

When at least one of the students' parents has a science & engineering job, the level of students' home-based science experiences tended to higher (t=2.260, p<.05) especially in designing and making activities (t=2.730, p<.005). The earlier the students decided their career, the higher levels of home-based science experiences (F=3.539, p<.05), recognition by family (F=3.466, p<.05), and family's supports (F=6.579, p<.005) they had. The levels of family's supports for science activities were highly associated with the levels of science experiences in all spaces, i.e., in classroom (β=.263, p<.05); out-of-classroom (β=.311, p<.05); and at home (β=.462, p<.001). The level of recognition by others was only associated with the levels of classroom-based science experiences (β=.298, p<.05) and its predictive power was higher than family's supports (β=.263, p<.05). A series of above outcomes imply a significant influence of home and family factors on science & engineering career decisions. Specifically, the level of home-based experiences in designing and making things were lower for our female participants than for male participants even though there was no gender difference in overall home-based experiences.

The history of measurement in Korean and Western cultures

Kim, Mikyoung, Ewha Womans University, Korea
Yang, Tai Gil, Daekyeong Middle School, Korea
Lee, Chae Yeon, Demonstration Middle School College of Education Ewha Womans University, Korea
Yoo, Hyuk-Keun, Demonstration Middle School College of Education Ewha Womans University, Korea
Lee, Je Sung, Choongam Middle School, Korea
Choi, Young-Jin, Ewha Womans University, Korea
Shin, Dong-Hee, Ewha Womans University, Korea
✉mkkim84@gmail.com

In a broader sense, measurement could be understood to a higher level of observation (Bong Woo Lee, Hee Kyong Kim, 2007), or the converting process of experience from outside world to quantitative term (Il Ho Yang et al., 2009). Measurement, scientific process to quantify nature, contains people's way of thinking. Along the history of measurement,

there is a social need for measurement and an understanding the view of thinking indirectly. History of measurement, which could identify the social and cultural features through science, is necessary to educate at this point, when 'integration' is emphasized. In this study, we compared and analyzed the features of view of thinking by researching the history of measurement in Korean and western cultures. To analyze the features of history of measurement, we researched the history of science in Korea and western culture through literatures, papers, and encyclopedia. We looked at the history of science in general, and sorted out the history related to measurement from the whole history of science. In addition, we drew social and cultural features of Korea and the West from the history of measurement.

As a result, Chosun Dynasty had mainly produced devices to observe meteorological phenomena such as Hemispherical Sundial (1434) and traditional rain gauge (1441). Chosun Dynasty developed devices to observe astronomical phenomena, and tried to record the observation such as Cheonsang Yeolcha Bunyajido (1395) and armillary sphere (1667). In contrast, in Western culture, mathematics, medicine, and physics were developed and as a result, scientific method was advanced. In Western culture, Pythagorean Theorem was proven in B.C. 550, and the infinitesimal calculus was developed in 1665. In addition, astronomy was advanced in the West, but in a different direction from Korea. In contrast to the fact that our ancestors tried to observe astronomical phenomena, western astronomy was developed to understand the relationship between the earth and the universe. It seems that Western culture tried to understand nature more analytically. Different ecological environment of Eastern and Western influences different political, economic, social, cultural and social systems, and social systems affect the metaphysical beliefs of people (Richard E. Nisbett, 2004).

Because of Centralism in the tradition, it was important to know the phenomena of sky to reinforce the authority of sovereign. As a result, many devices to observe meteorological and astronomical phenomena were used. On the other hand, the West thought they could control the nature, and the analytical studies, such as mathematics, physics and medicine, were developed.

Key words: Measurement, Korea, the Western culture, the way of thinking

The level of reflection writings toward science teaching with lesson study approach

Zainudin, Suhanna, National University of Malaysia, Malaysia
Iksan, Zanaton, National University of Malaysia, Malaysia
Othman, Mohd Izwan, Malaysia Ministry of Education, Malaysia
✉*suhanna.zainudin@yahoo.com*

Reflection on teaching is a vital process which is often neglected in the world of education especially among experienced teachers. Teaching reflection is an essential process of education for all educators to ensure that they can provide quality teaching and keep up on current trends and events. However the level of reflection by teachers must reach certain criteria that made the process of reflection thus having an impact on the development and improvement of teaching. This study explores the reflection made by the teacher-observers toward the teaching and learning of Science via Lesson Study approach. The findings of this study can contribute ideas to teachers in constructing quality reflection writing that could bring positive impact on teaching and learning. A study conducted for the observation and analysis of these documents has been accompanied by the 44 study participants, comprised of both experienced and new science teachers. This study discovered that most of the reflections made are in the forms of Descriptive Writing and Descriptive Reflection. Followed by Dialogue Reflection while there is no reflection made at the level of the highest reflection of Reflection Dialog. In conclusion, the level of reflection writing among science teachers are still low and needs to be polished to produce a reflection of writing that seeks to be a catalyst for the improvement of science teaching and learning process and thus, increasing the effectiveness of teaching and learning and teachers' professionalism. This study has also established a model teacher reflection on the teaching of science. This model can be used as a guide for teachers, researchers and the educational institution responsible in producing good reflections writing. Further research needs to be planned as well as programs that are appropriate to provide added value in the writing of teachers' reflection.

Relationships among academic, religious, and socio-economic variables

Ha, Minsu, Kangwon National University, Korea
Rachmatullah , Arif, Kangwon National University, Indonesia
✉*msha@kangwon.ac.kr*

Few studies have been conducted the relationships among all three variables-academic, religiosity, and socio-economic variables- although some studies have shown the relationship between two variables (e.g., academic and religiosity). In this study, we report the relationships among all three variables-education, religiosity, and socio-economic variables using, national level and large survey data. For the academic variable, we used PISA test scores of mathematics, science, and reading reported in 2006, 2009, and 2012, TIMSS test scores of mathematics and science reported in 2003, 2007, and 2011. To quantify the level of religiosity, we used the WVS data of six items on religiosity. To identify the socio-economical level of each country, we used Gross National Product, year of school from 2012 Human Development Index, and four variables (ladder, social support, freedom, and healthy life expectancy) of world happiness report. Total data of sixty eight countries were used in this study. We used the CATPCA to create the composite scores of academic level (using PISA and TIMSS scores), religious level (world value survey), and socio-economical level (GNP and etc.). Then, Pearson correlations and partial correlations were used to find the significance of relationship among three variables. The correlation coefficient between academic and religious variables was $r = -0.793$ ($p = 0.000$) and the partial correlations when the socio-economic variable was controlled was strong and significant ($r = -0.701$, $p = 0.000$). The correlations between religious variable and socio-economic variables was $r = -0.532$ ($p = 0.000$) and partial correlations when the academic variable was controlled was not significant ($r = -0.142$, $p = 0.251$). The correlations between academic and socio-economic variables was $r = 0.583$ ($p = 0.000$) and the partial correlation when the religious variable was controlled was significant ($r = 0.311$, $p = 0.010$). In this presentation, we discuss how education mediate religiosity and socio-economic variables based on our results and reviewed literature.

Educational shift of science and technology ethics in the national science curricula of Korea from the 7th in 1997 to the 2015 curriculum revision

Rhee, Hyang-yon, Ewha Womans University, Korea
✉*rheehy@ewha.ac.kr*

In order to explore the educational shift of science and technology ethics (STE) in the National Science Curricula of Korea, this study analyzed the curricula from the 7th in 1997 to the 2015 curriculum revision. Analysis factors were school level, curriculum item, subject of science, and the category of STE education. The category of STE education consists of 1) 'science inquiry ethics (SIE)', 2) 'science lap management (SLM)', 3) 'subject specific issues' including 'biomedical ethics (BME)', 'environmental ethics (EVE)', and 'engineering & technology ethics (ETE)', and 4) The social responsibility and role of science & scientists including 'science, technology, & society (STS)', 'socio scientific issues (SSI)', and 'social role of science & scientists'. The overall results showed that the STE education-related elements tended to have increased through the curriculum revisions, and a similar tendency showed in each analysis factor. STE education-related elements were greatly increased as teaching-learning and evaluation methods were introduced in each lesson unit in the 2015 curriculum revision. Out of all the STE education-related elements, SIE have increased the most and the number of the contents was the highest in the whole curricula. In the 'subject specific issues', EVE was the

highest while BME was lowest. ETE in physics, SIE in chemistry, and EVE in biology were the most frequent elements in each science subject. STS and SSI elements appeared to have relevantly less increased because overall STS and SSI education elements were subdivided to the specific ethical elements in this study. Consequently, STE education in the National Science Curriculum in Korea has achieved the quantitative expansion. However, the qualitative evaluation involving reflection to the absence of social responsibility of science & scientists should be necessary.

SSI in Japan: The lack of "uncertainty" as NoS

Ishikawa, Satoko, Osaka Kyoiku University, Japan
✉*sisikawa@cc.osaka-kyoiku.ac.jp*

Why has SSI (socio-scientific issues) been failing to establish popularity in Japan? This paper discusses the answer to this question through the comparison of SSI and a unit "Science, Technology and Humans (STH)", for the secondary level school science in Japan.

According to the course of study, the unit's objective is "to enable students to deepen recognition of the relationship between the use of energy resources and scientific and technological developments with human life, as well as to foster an attitude of scientifically consideration and judging modalities for the conservation of the natural environment and the use of science and technology." In particular, it aims to encourage students to sort out the strong and weak points of the use of science & technology and, when several priorities remain incompatible with each other, to make decisions based on scientific grounds. There are two aspects that are distinct from SSI, while the unit is similar to SSI in terms of decision-making concerning how science and technology are in society.

First, whereas SSI, as its name shows, aggressively deals with the actual issues related to science and technology in the society, STH obscures the social aspects of science. The second point is the acknowledgement of NoS (Nature of Science), especially the uncertainty of scientific knowledge that forms the basis of SSI and STH. Evidence and proof used in judging SSI may possibly include uncertainties of scientific knowledge, so SSI is based on the views of science that scientific knowledge may involve uncertainties. On the contrary, Japan's course of study defines "scientific" as "verifiable", "replicable" and "objective" without leaving room for uncertainties.

For SSI to take a hold in Japan, science educators in Japan must reflect on and incorporate the views of science in the course of study which forms the basis of science education.

Exploring Korean medical students' various perceptions on mind-body problem: Empirical findings from latent class analysis

Shin, Sein, Chonbuk National University, Korea
Lee, Jun-Ki, Chonbuk National University, Korea
Yoo, Hyo-Hyun, Chonbuk National University, Korea
Rachmatullah, Arif, Kangwon National University, Korea
Ha, Minsu, Kangwon National University, Korea
✉*sein3027@gmail.com*

Since Cartesian mind-body dualism was addressed in 17th century, mind-body problem have been long-lasting issue in philosophy and science. Practically individual perspective on relationship mind and body affects their behaviors either explicitly or implicitly. Especially bio-medical professional, who treat human body and mind practically, treat their patients differently depends on their perspective on mind-body problem. The purpose of this study is to identify classes among medical students with their distinct perspective on mind-body problem. For this research purpose, first, polytomous latent class analysis (poLCA) was conducted with sample of 507 Korean medical students. poLCA results showed that there was three distinct classes among medical students: Mild emergentism class (56.6%), Monism class (38.7%), and Dualism class (4.7%). Second, to understand each class's perspective on mind-body problem in detail, we analyzed students' text explanation about mind-body relationship in terms of latent class. Result showed that majority of medical students' believe mind-body relationship with emergentism, which means they perceive mind and body qualitatively different but they focused on mutual interaction between mind and body. Lastly using chi-square analysis we examined the relationship between their class membership and gender, academic year, religion, and death experience of their close people. There was significant difference among latent groups on academic year. Considering the fact that mind-body problem is deeply related with students' perception of life concept and their future bio-medical practice, medical education considered the medical students' distinct perception pattern of mind-body

Korean and Indonesian pre-service science teacher's attitude towards environment

Lee, Sangeui, Kangwon National University, Korea
Park, Eunju, Kangwon National University, Korea
Rachmatullah, Arif, Kangwon National University, Indonesia
Ha, Minsu, Kangwon National University, Korea
Lee, Junki, Chonbuk National University, Korea
✉*leese0708@naver.com*

In the last decades, environmental damages arising on the earth are getting bigger and more happening and it presumably caused by humans' attitude towards the environment. Consequently, research on investigating citizens' attitude towards environment have been carried out and become more prevalent. It has been known that cultural and economic backgrounds (e.g., culture, religion, GNP) can affect people's attitude towards the environment. This study was purposed to explore the differences between Indonesian and South Korean pre-service science teachers' attitude towards the environment. We employed the fifteen items of the revised New Ecological Paradigm (NEP) based on the value orientations (biospheric, altruistic and egoistic) as our research instrument. A total of 273 pre-service science teachers (n=149 in Indonesia and n=124 in Korea) participated in this study. We performed Rasch analysis for investigating the dimensionality, item fit, and differential item function (DIF). Then, we used the Independent Samples T-test, and the Pearson correlation test to explore our research questions. We found that the three-dimension model is the best compared to the other models. We found no DIF between countries and item fit indices are met the cut-off. Our findings show that the Indonesian showed significantly higher altruistic value compared to the Korean, while the Korean showed significantly higher egoistic value compared to the Indonesian, We also found a high, negative correlation between altruistic and egoistic values in the Indonesian sample, but found no significant correlation in the Korean sample. Based on our findings, we will discuss relationships between cultural, economic factors and pre-service science teacher's environmental attitudes.

Elementary school student's recognition by open inquiry

Bang, Sin Young, Pusan National University, Korea
Kim, Hyo-Nam, Korea National University of Education, Korea
✉*siniga@hanmail.net*

The purpose of this study was to investigate elementary school students' recognition after conducting free inquiry adopting different grouping methods by cognitive levels to derive implications for application of effective grouping methods in educational course. This study is to investigate how students think about free inquiry as well as grouping and the preference of grouping methods in free inquiry adopting different grouping methods. Twenty 6th graders participated in this study and were conducted free inquiry by homogeneous or heterogeneous groups according to cognitive levels. After finishing free inquiry, a semi-structured interviews was conducted with the students. Students' free inquiry diary and teachers' observation logs and anecdotes are collected and analyzed.

The results of this study showed that the students were interested in free inquiry because of conducting it with their friends together, and high level students of heterogeneity and high attentive students in homogeneous group thought it was difficult. Although high level students in heterogeneous

group and girls in homogeneous group were attentive in participation of free inquiry, role division was decided well in heterogeneous group and was not decided well in the homogeneous group. The degree of participation of students in the discussion was low. Students in hemogeneous group recognized role division as an advantage, and students in hemogeneous and high level group, performing experiments well and expressing their thoughts, and students in hemogeneous and low level, understanding each other easily. The faults of grouping are that some of students did not take the initiative in the experiment in heterogeneous group, and role division was not decided well in the homogeneous group, especially high level homogeneous group recognized they were sturdy in argument as an demerit. Low level students in heterogeneous group and students in homogeneous group who participated in discussion passively were satisfied. Satisfaction of heterogeneous gruop was higher than that of homogeneous group. Most students prefer heterogene of grouping in terms of ability or attitude.

Teachers should make class hours for free inquiry activity, discussion activity, and develop teaching skills of role division for effective group study. Also it is necessary to proceed studies of the effectiveness of various student variables and several variables that influence group study.

The effects of the middle school students' conceptual changes on buoyancy by experimental videos for demonstration using a quantitative method and a qualitative method

Kim, Yi Young, Pusan National University, Korea
Kim, Ji Na, Pusan National University, Korea
✉*lykim@pusan.ac.kr*

The purpose of this study was to understand middle school students' buoyancy conceptions and conceptual change by the experimental videos for quantitative demonstration using spring scales and qualitative demonstration using a beam scale. 267 middle school students were tested pretest. Among the 267, 128 students were selected who answered all of question in the test. The buoyancy concept test composed of 9 items were developed. In this study two different experimental videos for demonstrations were adopted; the first one is using spring scales, and the second one is using a beam scale. Experimental videos for demonstration were presented on three items which showed lower scores than other items in the pretest. The research procedure were as follows: Pretest → presentation experimental videos → test of cognitive conflict levels → lesson on the buoyancy concept → posttest → delayed posttest (after one month). The scores in the multiple choice and scientific conceptions were significantly increased in both of the groups. Therefore, both of the groups were effective for scientific conceptual changes. Spring scales group showed higher scores in the multiple choice items as well as change of scientific conceptions than a beam scale group. Therefore, experimental videos for quantitative demonstration using spring scales are more effective than qualitative demonstration using a beam scale for conceptual changes. In case of formal operational period students, experimental videos demonstration using a beam scale were more effective than using spring scales; however, in the case of concrete operational stage students, using spring scale were more effective than using a beam scale in conceptual change. The students who had changed from misconceptions to scientific conceptions showed higher cognitive conflicts levels than those who were not changed their preconceptions.

The effects of the application of backward course design in elementary school science on 'biological and environmental' section.

Ham, Junghwa, Pusan National University, Korea
Sim, Jaeho, Pusan National University, Korea
✉*fishing315@naver.com*

The purpose of this study was to analyze the effects of the application of backward course design on 'biological and environmental' section in elementary school science. Backward design starts from a specification of learning outcomes and decisions on methodology and syllabus are developed from the learning outcomes. The design model of Backward curriculum is able to maintain consistency between educational contents-evaluation-learning activities and also able to promote student's understanding. The 78 students 6th graders participated in this experiments. Data was collected using the Science Academic Emotion Scale, Academic Achievement, and Science Teaching Efficacy Scale. The collected data was analyzed by frequency analysis, t-test, and ANOVA analysis using the SPSS 23 statistical program. The following major conclusions were drawn on the basis of data analysis: First, there were statistically differences between the group taken the instruction based on backward curriculum design and the other group taken the traditional instruction. Second, the interaction effect of the instruction based on backward curriculum design and Science Academic Emotion was not significant statistically. Third, also the interaction effect of the instruction based on backward curriculum design and Science Teaching Efficacy was not significant statistically. However, the interaction effect of the instruction based on backward curriculum design was seen that after the ends were aware of the objective for a long time.

AUTHOR INDEX

AUTHOR INDEX

Asia History, Philosophy of Science and Science Teaching 2016 Conference

Organizer

Research Institute for Science Education, Pusan National University

Chairs

Kim, Youngmin, Pusan National University
Seo, Hae-Ae, Pusan National University

Organizing and Scientific Committee

Sim, Jae-Ho, Pusan National University
Nam, YounKyeong, Pusan National University
Kim, Ji Na, Pusan National University
Nam, Jeonghee, Pusan National University
Song, Sung Su, Pusan National University
Park, Young-Shin, Chosun University
Park, Jongwon, Chonnam National University
Song, Jinwoong, Seoul National University
Martin, Sonya, Seoul National University
Park, Jongseok, Kyungpook National University

부산대학교 학술대회 준비위원회

위 원 장: 김영민 (부산대학교 물리교육과)
서혜애 (부산대학교 생물교육과)
준 비 위 원: 심재호 (부산대학교 생물교육과)
남윤경 (부산대학교 지구과학교육과)
김지나 (부산대학교 물리교육과)
남정희 (부산대학교 화학교육과)
송성수 (부산대학교 물리교육과)
준 비 보 조 원 윤진아 (부산대학교 대학원 영재교육전공)

[46241] 부산광역시 금정구 부산대학로 63번길 2(장전동) 부산대학교 과학교육연구소 (공동연구소동 510, 511호)
Research Institute for Science Education, Pusan National University (Gongdong Research Institute Building #510, 511)
2, Busandaehak-ro 63beon-gil, Geumjeong-gu, Busan, 46241, KOREA

TEL: 051.510.1877 FAX: 051.581.5654 E-mail: sciedu@pusan.ac.kr, http://asiahpst2016.pusan.ac.kr

ASIA HISTORY, PHILOSOPHY OF SCIENCE AND SCIENCE TEACHING 2016 CONFERENCE

아시아 과학사과학철학과학교육 2016 학회

ORGANIZED BY

Pusan National University
Research Institute for Science Education

SUPPORTED BY

Pusan National University