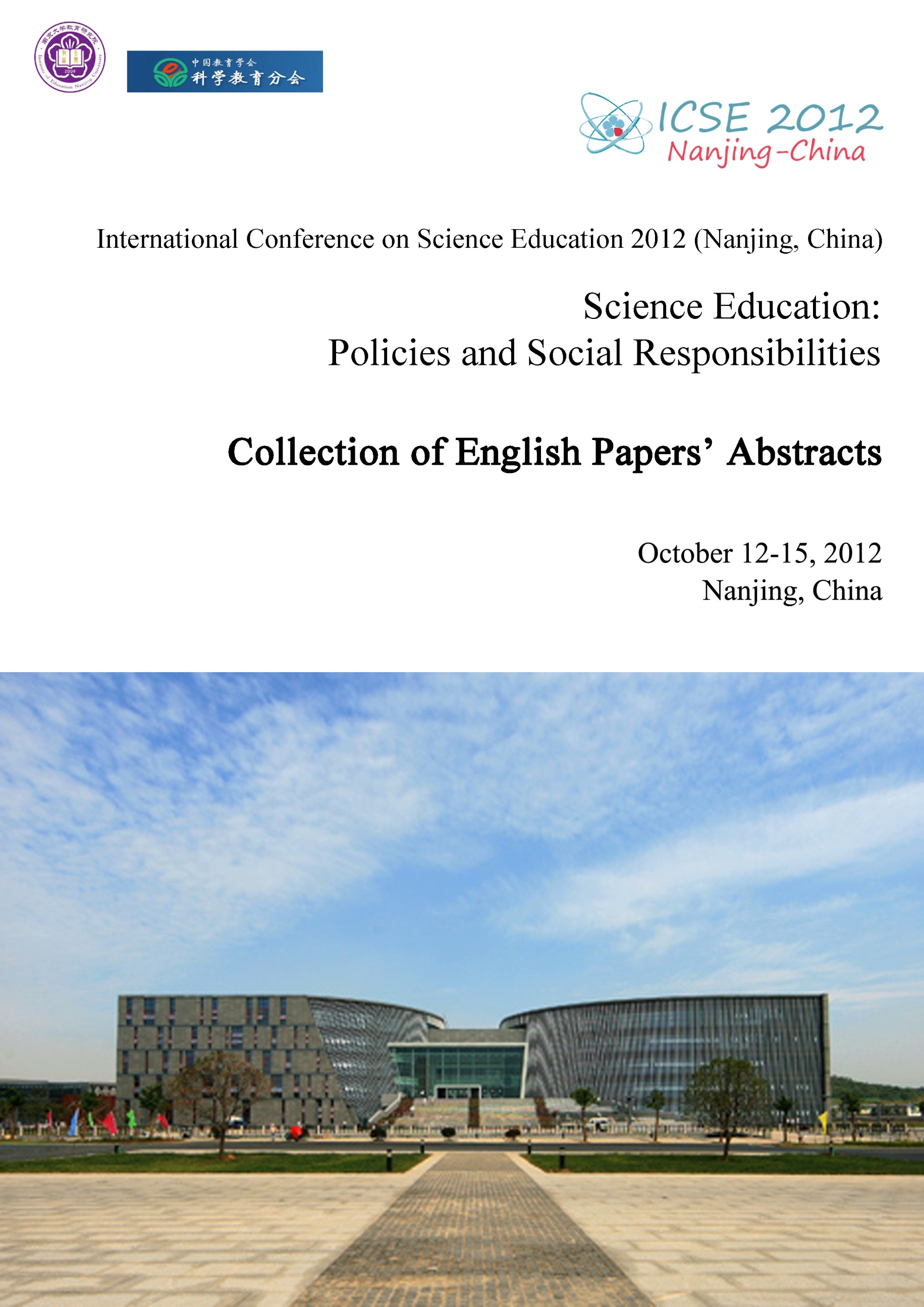
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英文论文集宣传预留页

Introduction to Collection of Conference Papers’ Abstracts

This collection contains English papers’ abstracts presented in the International Conference on Science Education 2012 (ICSE2012, Nanjing, China), held at Nanjing University, China on Oct.12-15, 2012.

Science education research is vital in the development of national science education policies, including standards, teacher development and public understanding of science. Science education researchers study the quality, feasibility, and alignment of standards at different levels with regard to curriculum materials, assessment practices, and science teacher certification requirements; they also seek ways to bridge formal and informal science education. Science education research thus affects a nation’s ability to fulfill its social responsibilities.

The ICSE 2012 conference welcomes science education researchers from around the world to exchange experiences, challenges, and strategies in science education research, particularly in areas related to development, implementation, and evaluation of science education standards, connections between formal and informal science education and to science teacher education in their countries.

The papers that were accepted by the international review committee cover a wide range of subjects and research methods. They embody a mix of theory and practice, planning and reflection, participation and observation to provide the rich diversity of perspectives represented at the conference.

All the papers for ICSE2012 were reviewed by at least two members of the following international review committee. With many thanks for their input:

Prof. Baohui Zhang, Institute of Education, Nanjing University, China, Co-Chair;

Prof. Hongshia Zhang, Institute of Education, Nanjing University, China, Co-Chair;

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Prof. Hua Xiang ，Beijing Normal University, China;

Prof. Hua Li ，Beijing Normal University, China;

Dr. Haiwang Huang, People's Education Press;

Prof. Rui Wei, Beijing Normal University, China;

Prof. Zhen Lu, Nanjing Normal University, China;

Prof. Qiyong Cai, YangtZe Normal University, China;

Ms. Linghong Meng, Beijing Institute of Education, China;

Mr. Xiangdong Wu, South China Normal University Affiliated Elementary School, China;

Mr. Xinqi Lu, National Association for Science Education the Chinese Society of Education (CNASE), China;

Ms. Ling Chen, China Research Institute for Science Popularization, China;

Mr. Dongsheng Wan, Nanjing University;

Dr. Ying Tao, West Australian University, Australia;

Ms. Yin Zhang, Guangxi Normal University

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Keynote Speeches

## Inclusive STEM High Schools: Improving Educational Opportunity and the Economy

Sharon J. Lynch

George Washington University

slynch@gwu.edu

Abstract: This paper introduces a new research project that focuses on an innovative type of school that is quietly emerging across the US, *Inclusive STEM-focused High Schools (ISHSs*). Unlike older, highly selective STEM-focused schools that target students already identified as being STEM gifted/talented, the goal of ISHSs is to develop new sources of STEM talent among underrepresented minority students, and provide them with the means to succeed in school and in STEM jobs, college majors, and careers. ISHSs have the exciting potential to create entirely new opportunity structures for students underrepresented in STEM fields because they may make connections between K-12 schooling, higher education, and STEM jobs and careers through innovative education programs that are delivered at the school level, but expand the boundaries of the normal school day and year. These schools blur formal and informal education, and can potentially reconfigure relationships among teachers, students, and knowledge. Their innovative school designs are pushing limits for practice by engaging students with their communities, STEM business and industry, and early opportunities for higher education experiences. However, ISHSs are a new phenomenon and their ability to meet their goals (raising the STEM achievement of underrepresented students and creating new learners ready for college STEM majors and careers) has not been well-documented in the research literature. The study’s multiple instrumental case study design allows systematic comparisons across 12 ISHSs using descriptive statistics and common rubrics. The study offers a core set of 10 candidate critical components likely shared by well-established ISHSs. At present, the first case study has been conducted at Manor New Tech High School in the state of Texas. The case describes how each component was designed and implemented at the school and an interdisciplinary STEM curriculum that relies entirely on project-based learning. In addition to hypothesized critical components, other factors appear to contribute to the school’s success. Student outcome data indicate positive effects for students who attend the school, compared with the other Texas high schools. This paper offers an opportunity to see a unique U.S. school design, as well as the conceptual framework designed to analyze it.

## Implications of the K -12 Science Education Framework and Next Generation of Science Standards for Teaching and Learning

Joseph Krajcik

Institute for Collaborative Research for Educational Assessment and Teaching Environments (CREATE) for STEM, Michigan State University

**Abstract：**In this session, I will present an overview of the K – 12 Framework for Science Education and how the ideas synthesized from the Framework form the foundation for the Next Generation of Science Standards (NGSS). I will explain four principles that arise from the Framework: Core Ideas, Crosscutting Concepts, Scientific and Engineering Practices and Development of Understanding Across Time. I will end the session by discussing the implications of NGSS for teaching and learning.A major finding from the Framework argues that standards and curriculum materials should be focused on a limited number of ideas that will allow learners to develop understanding that can be used to solve problems and explain phenomena. As such, scientists and science educators identified four core ideas for each science discipline. The goal was to identify a coherent and limited set of disciplinary ideas that all students will need to apply in their lives and that can be developed and become more sophisticate throughout the K – 12 curriculum. Core ideas are essential to the discipline and help to explain phenomena central to the discipline. Examples of core ideas include energy, evolution, and earth systems. Crosscutting concepts are those ideas important to all science disciples. Examples include cause and effect, systems, and scale and proportions. A second major finding is that learners need to engage in scientific and engineering practices to learning core ideas and crosscutting concepts. The learning of content cannot be separated from the doing of science and vice-versa. Scientific and engineering practices can be considered the multiple ways of knowing and doing that scientists and engineers use to study the natural and design world. Examples of scientific and engineering practices include constructing and revising models and using evidence to support claims. A third major finding from Framework is that learning develops as a continuous process across time and that new understanding is constructed on a foundation of existing understanding and experiences. As such, learning new difficult ideas requires time and becomes more sophisticated as students engage in tasks that require learners to synthesize and apply the ideas. The Next Generation of Science Standards builds from these principles in the Framework to develop standards that include performance expectations that integrate scientific and engineering practices, crosscutting concepts, and disciplinary core ideas. As such, the NGSS express standards in terms of performance expectations that require students to demonstrate knowledge-in-use. Moreover, the NGSS need to present a coherent set of standards so that learning can build overtime. Clearly specified standards expressed as performance expectations can drive the alignment among curriculum, assessment, and instruction to enhance student learning. Although the NGSS is a major step forward in improving the teaching and learning of science, much work still needs to occur with developing new curriculum materials and assessments that align with standards. Moreover, extensive professional development needs to occur to help various professionals – assessment developers, curriculum developers and teachers, understand the new standards.

## Preservice Science Teacher Education: What Can China and the US Learn from Each Other?

Dr. Xiufeng Liu

State University of New York at Buffalo

Abstract：Improving science teacher education is a focus of science education reforms in many countries. In this presentation, I first review current research on models of preservice science teacher education including undergraduate and graduate models. Drawing from theoretical frameworks of teacher knowledge (e.g., pedagogical content knowledge – PCK) and education research traditions (e.g., empirical and pedagogical research), I then compare and contrast preservice science teacher between the US and China in terms of sources of teacher candidates, preservice science teacher education curriculums, and student teaching experiences. By identifying the strengths and weakness of each country’s theories and practices, I propose specific areas that each country can learn from the other. Preservice science teacher education is one component of the larger education system that is situated in a country’s historical, cultural and political contexts; best preservice science teacher education theories and practices must reflect these contexts.

## The Development, Implementation and Evaluation of Science Education Standards in Germany

Peter Nentwig

Leibniz Institute for Science and Mathematics Education at the University of Kiel (IPN)

peter.nentwig@gmx.de

Abstract: Traditionally, science education in Germany was input-steered by the syllabus. It specified what teachers were required to teach grade by grade, subject by subject. The underlying implication was that students would learn what was taught. What common sense had long doubted was officially attested in 2001 with the first PISA results: input and output were not congruent. German 15-year-olds performed below expectation. Therefore the "Standing Conference of the Ministers of Education and Cultural Affairs of the Länder in the Federal Republic of Germany" (KMK) decided to change the system from input-orientation to output-orientation. In 2003, achievementstandards were issued for German language, Mathematics, and first foreign language, followed in 2004 by biology, chemistry and physics. These standards specify what students were expected to have learnt by the end of lower secondary education (grades 9 or 10, students about 16 years old). While syllabi in the past had strongly focused on content, the new standards for the science subjects present four "areas of competence", only one of which covers the traditional content (knowledge of science). The second, closely related area deals with epistemological and methodological issues (knowledge about science). Areas three and four, previously often concealed in the syllabus' preamble, now officially rank as "communication competence" and "judgment competence". Parallel to explicating these areas and specifying them with exemplary tasks, basic concepts were selected for each subject to which the competences apply, and levels of achievement were defined. Germany being a federal republic of 16 states, it was then in the states' authority to subsequently implement the standards issued by the KMK into their school systems. They were mandatory from the academic year 2005/06. In order to monitor the target achievement of the new output-orientation, the Institute for Educational Progress (IQB) was founded with the major task to develop, conduct and evaluate tests, which have since been attached to the regular PISA procedures. The German process of developing, implementing and evaluating standards for science education is presented and discussed in the context of similar developments in other countries.

Keywords: standards, competences, learning outcomes, secondary education

## An Overview of Science Education in Nigeria

Ben Akpan

**Abstract**：The paper provides an introduction to science (and technology) education in Nigeria within the context of the general goal of science education (especially its dual mandate), the position of the Economic Commission for Africa on science and technology education, and the status of Nigeria within the African region. Struggling economies and low human development indices mean that all is not well with Africa as it continues to rely on external financial support for its educational programmes often targeting short-term activities and solutions. Until recently, Africa did not give science, technology, and innovation the serious attention they deserve as engines of long-term development. Even so, general economic development in Africa is dominated by its own ‘G-4’, namely the SANE countries of South Africa, Algeria, Nigeria, and Egypt. Yet Africa’s best performing economy, South Africa, only places a distant 25th globally in terms of Gross Domestic Product (GDP) at Purchasing Power Parity (PPP). Given this rather bleak background, it is interesting to examine the direction of science and technology education in Nigeria as one would not be surprised to find a multiplicity of constraints to the progress of that sector. In fact, studies by the World Bank on Nigeria have revealed interesting findings in the areas of policies on science, technology and innovation; teaching and learning, curricula and assessment practices; and labour market responsiveness viz-a-viz the supply and demand for science and technology graduates. Some of the findings indicated some lapses ranging from inadequate resources, overcrowded classrooms to ill-motivated teachers, resulting in poor teaching and subsequent learning of science and technology subjects in schools and colleges. Upon a review of these findings and conclusions, the Federal Government of Nigeria thought that there was a need for an overarching, achievable, and affordable strategy for science and technology education in Nigeria and thus went ahead to initiate a number of policies and programmes that are meant to alleviate the constraints in the sector. Two of these are the Nigeria-UNESCO Special Science and Technology Education (STE) project, which has come to an end; and the World Bank – supported Science and Technology Education Post-Basic (STEP-B) Project, which is on-going. These intervention projects are already yielding very positive results as Nigeria appears to be heading in the right direction. Indeed, these reforms are within the purview of the current Plan of Action of African Union’s Second Decade of Education for Africa. Of course this introduction to science education in Nigeria within an African regional context would be incomplete without an examination of the situation in other African countries. For this purpose, developments in science education are provided in respect of Algeria, Egypt, Ghana, and South Africa. It is hoped that the Nigerian as well as other national governments in Africa will sustain the tempo of the present reforms in order that the anticipated benefits will be fully realized.

**Key Words**: Africa, dual mandate, science and technology education, economy, sustainable development, constraints, intervention, post-basic.

## How to enhance the quality of science lesson in Japan?

Shigeki KADOYA

Curriculum Research Center, National Institute for Educational Policy Research

Email: skadoya@nier.go.jp

Abstract: The Courses of Study, or Japanese National Curricula, stipulate that each school should be committed to enhancing its instruction to enable pupils to solidly acquire basic and fundamental knowledge and skills, to foster the ability to think, to make decisions, to express themselves (pupils' ideas) and other abilities that are necessary to solve problems. This study first touches on the three decades of history of the Courses of Study. It discusses, then, what kind of abilities should be fostered in science education. After clarifying the acquisition of basic and fundamental knowledge and skills in science education, this study elaborates the practical strategies aiming to foster the three abilities and to cultivate an attitude described in the Courses of Study that are following: (1) practical strategies fostering the ability to think, (2) practical strategies fostering the ability to make decisions, (3) practical strategies fostering the ability to express themselves (pupils' ideas), (4) practical strategies cultivating an attitude of proactive learning and developing pupils' individuality. Moreover, the practical strategies aiming to foster several abilities in science education will be discussed as bellow: (5) practical strategies fostering the ability to learn the basic scientific conceptions and skills, (6) practical strategies encouraging pupils' scientific inquiry. Having demonstrated these practical strategies, this study further discusses the problem-solving processes aiming to foster the abilities. Lastly, considerations in the language activities will be presented that is emphasized on the new Course of Study.

Keywords: Japanese National Curricula, foster the abilities, history of science curricula

## Training for Science Teachers in Primary and Middle School and the Development of Science Education Profession in China

PENG Shujin

Sichuan Normal University, China

Abstract: A directional pattern had been adopted during the training for China's science teachers in primary and middle school. However, the curriculum reform for basic education has been vigorously developed since the turn of the century. With the rise of science curriculum reform in primary and middle school, the birth of a new major for teacher education, Science Education which aims to train comprehensive science teachers as goal has changed the directional training pattern. After ten years’ development and progress, Science Education has win initial success, which has formed training characteristics in orientation, objective, pattern and the diversity of professional curriculum structure. From the point of view in training system evolution and development for China's science teachers in primary and middle school, this article focus on the review and prospects for training idea, target and curriculum structure developed in the ten year’s construction and progress of Science Education.

Key words: China, Science teachers in primary and middle school, Science Education, Development Trend

# National/Local Science Education Standards

## Examining the Impact of Globalization at the Macro, Meso, and Macro Levels: Employing Intersectionality and Cultural Sociology to Understand the Impact of Immigration on Science Teaching and Learning in the United States

Sonya N. Martin

Seoul National University, Seoul, Republic of Korea

Email: sonya.n.martin@gmail.com

Abstract: Using complementary theoretical frameworks, intersectionality and cultural sociology, researchers can gain multifaceted understandings about the challenges students, teachers, and researchers face in teaching and learning science and in conducting science education research in linguistically and culturally diverse contexts. Advocating for research that connects aspects of globalization and migration from macro, meso and micro-levels, this study discusses the need to contextualize the complexity of issues researchers must contend with when drawing generalizable conclusions about students’ needs and science learning experiences. This paper raises questions about the role of research at different levels to make sense of how migration is shaping immigration in the United States (macro) and how teacher preparation and policies regarding the education (meso) of immigrant students is affecting science instruction methods in K-12 classrooms (micro). Implications are drawn for local practice regarding the need for teachers to challenge their understandings about what it means to teach immigrant and language minority students science in this era of globalization.

Keywords: intersectionality, sociocultural theory, globalization, immigration

## The Call to Innovate: Transformed Notions of the Purpose of STEM Education in Australia

Tanya Doyle

James Cook University, Townsville, Australia

Email: tanya.doyle@jcu.edu.au

Abstract: Science, technology, engineering and mathematics (STEM) education in Australia has been previously described as at crisis point with calls to re-imagine science education in order to address the crisis. This call comes at a time of political and economic transformation in Australia. Federally, the education policy moment is dominated by the articulation of an Education Revolution underpinned by neoliberal market ideologies. As well, Australia’s economy has transitioned to post-Fordism and accordingly, Australia seeks to galvanise its ‘knowledge economy’ in what it sees as ‘the Asian Century’. It is through policy that ‘Innovation’ is re-positioned as critical to Australia’s future economic prosperity. Education, particularly STEM education -and specifically education in the ‘enabling sciences’ of physics and chemistry, is in turn centrally positioned in the transformation of an ‘Innovative’ Australian citizenry. Despite the Federal political agenda to transform the nation state into ‘Innovators’ who ‘know Asia’, many students who attend secondary schools experiencing high levels of social and economic disadvantage continue to study in fields outside of the ‘enabling sciences’. This paper presents findings from a mixed method study in regional Australia. It argues that while policy attempts to engage students in STEM education and harness teachers and the STEM curriculum as tools to shape the ‘Innovative’ human capital required in a neo-Schumpeterian knowledge economy, tensions arise from such transformational attempts - tensions between the political purpose of STEM education and the ways in which the students themselves respond to and evaluate these attempts as relevant to their lived experiences.

Keywords: STEM education; Innovation; knowledge economy; policy

## A study of the processes of establishing and practicing a ‘professional policy' of national science education

Sung-Jae Pak

Seoul National University, Republic of Korea

paksj@snu.ac.kr

Abstract: A series of surveys of a few countries' processes of establishing and practicing 'professional policy' in the national science education (ppnse) has been designed by this researcher. The case of the United State has been pursued to understand its history in the last half century related with the 'Alphabet Soup Science’ in the 1960s, 'Science・Technology・Society' in the 1980s, and the ‘National Science Education Standards (NAES)' in the 2000s by the supports of the ‘administrative policy’ in national science education(adnse). Science education would not be pursued successfully through a biased approach of over-emphasizing the nature of science or interest of children. Also, however urgent the needs of the nation and society are—or payments as "... it took $7million and four years of debate to produce the 262-page NSES publication in 1996”—science education should not be tied only to social issues. Tendency to centralize national policy of science education in the United States has been observed. Democratic processes of establishing and practicing of the ppnse is impressive and perspective. This study suggests that we may try a cooperative work for the 'Global Science Education Standards' which take care of 'every' youth through a ‘co-generative’ way at formal and informal settings in 'all' countries on Earth.

Keywords: professional policy, administrative policy, national policy of science education, science education standard, comparison of science education

## Policies for Broaden Implementation of Research-Based Pedagogy in Undergraduate STEM Education: Possible Models, Limitations, and Solutions

Gavin W. Fulmer

National Institute of Education, Singapore

Email: gavin.fulmer@nie.edu.sg

Abstract: Research and development on reformed methods of undergraduate STEM instruction has identified various pedagogies to support students’ learning. Yet despite growing research and attention, undergraduate STEM instruction still primarily follows traditional, lecture-based formats. This limited implementation of research-based pedagogies has frustrated education researchers and key policymakers, and demonstrates the need to identify promising models to support the implementation of research-based pedagogies in undergraduate STEM education. This paper describes selected models that reflect different stances on the relationship among STEM educators, institutions of higher education (IHEs), and state and federal policymakers. The models are grouped into two classes: policy-oriented models, and facilitation-oriented models. Problems with the models, and possible solutions, are also presented.

Keywords: STEM education, undergraduate education, education reform, discipline-based education research, US education policy

## Stability and Trends in High School Chemistry Curriculum Standards: By Comparison of International Curriculum Standards

Lei Wang

Institute of Chemical Education, Beijing Normal University, China

Email: wangleibnu@126.com

Mingchun Huang

Institute of Chemical Education, Beijing Normal University, China

Email: hmc91810@126.com

Weizhen Wang

Institute of Chemical Education, Beijing Normal University, China

Email: vijane@126.com

Yanxia Jiang

Institute of Chemical Education, Beijing Normal University, China

Email: jyx814@163.com

Lina Zhang

Beijing Normal University, Institute of Chemical Education

Email: linacat630@sohu.com

Ronghui Zhang

Institute of Chemical Education, Beijing Normal University, China

Email: zrh8810@163.com

Abstract: Through pairwise comparison on high school Chemistry curriculum standards between China mainland and other countries/regions, we found that there are some similarities in high school Chemistry curriculum standards. So we extracted six keywords that reflected the commonalities and trends. Based on each keyword: curriculum structure, learning progressions on Chemistry core concepts, the breadth and depth of Chemistry knowledge, performance standard, the demand of ability, curriculum evaluation, we did the special research .From which we got many enlightenments in curriculum design, built a preliminary progress map of Chemistry core concepts, learned about the breadth and depth of Chemistry knowledge in different countries/regions.

Keywords: Chemistry curriculum standards, curriculum structure, learning progressions on Chemistry core concepts, the breadth and depth of knowledge content, performance standard, the demand of ability, curriculum evaluation

## History and Challenges of Integrated Science Curriculum Implementation in Zhejiang

Xiao Huang

Education College of Zhejiang Normal University, China

Email: huangxiao@zjnu.cn

Abstract: The integrated science of Zhejiang Province has lasted nearly 20 years, beginning from the three experimental areas in 1991 to the whole province in 1993. With the development of curriculum reform, effective implementation of science curriculum is stressed which necessitates the study and solution of several problems in science practice. Thus, we will show the history of integrated science curriculum to identify the problems and determine the most effective means of implementing the course formation, goals, strategies, evaluation, mechanisms of science learning, teacher professional development, and other dimensions. In the present study, classroom observation, surveys, and interviews of teachers and students are used to bring light to series of questions, such as : How did the integrated science curriculum of Zhejiang province develop? Is it similar to the process experienced in other provinces? What are the issues encountered during the implementation of the integrated science curriculum? What are the effects of these issues on the implementation? To answer the questions, we follow two steps:(1) We review the history of science curriculum from "the natural science" to "science" curriculum to know the development process in detail.(2) Likert questionnaires regarding the integrated science implementation and the understanding of the nature of science by science teachers are designed and conducted. And interviews are utilized to analyze the pros and cons of science curriculum implementation. Thus, several conclusions are drawn: (1)"integrated science" and "combined science” are con-exist in science teaching practice. (2)Almost science teachers pay more attention to the specific dimensions of knowledge and show a lack of concern regarding students’ understanding the nature of science, which is necessary in the current evaluation system. (3) As to scientific inquiry and cooperation, further study is needed, not only into the effectiveness of inquiry and cooperative necessary, but into the operational evaluation of scientific inquiry as well. (4) Although the role of information technology is impressed in all science classrooms, it is often limited to presentations, lacking resource functions and interactive features. As for the Digital Information System (DIS), most science teachers remain unfamiliar with these technologies in science teaching.

Keywords: science, integrated science curriculum, curriculum implementation, scientific literacy, the nature of science

## Representations of Nature of Science in Selected Histories of Science in the Integrated Science Textbooks in China

Wei Bing

University of Macau, Macau

bingwei@umc.ma

Chen Bo

Li Yue

Abstract: This study aimed to examine the representations of nature of science (NOS) in the eight histories of science selected from three series of integrated science textbooks used in junior high school in China. Ten aspects of NOS were adopted in the analytical framework. It was found that NOS had not been well treated in the selected histories of science in the three series of science textbooks. Specifically, it was found that the empirical and inferential aspects were treated better than other aspects, and discrepancies existed among the three series of science textbooks and among the eight histories of science in terms of dealing with the target NOS aspects. Implications for addressing NOS in historical materials in science textbooks were discussed in the final part of this paper.

**Key words** Nature of science, history of science, science textbook

# Science Teacher Education

## Impact Analysis of Student Centered Inquiry Based Project and its Implications on Standards of Science Curriculum in Pakistan

Alyas Qadeer Tahir

National Institute of Science and Technical Education, Islamabad, Pakistan

Email: ilyasqadeer@yahoo.com

Abstract: The quality of in-service teacher education for elementary school teachers of Pakistan, when compared with that of many other developing countries, has been found to exhibit a number of serious deficiencies. The National Science Education Standards, Pakistan requires teachers to use inquiry approach for enhancing the quality of education through the New National Curriculum implemented from the year 2010. The main theme of General Science for Grades IV– VIII is “student-centered and inquiry-based (SCIB) learning”. This approach ultimately aims to lead to the quality of in-service teacher education in the country with the adaptation of new teaching methods in line with standards of the new science curriculum. The assessment of science teacher’s needs strongly advocated for an infrastructure of training of science teachers which supports in delivering the lessons effectively and making the science activities interesting. The Japan International Cooperation Agency (JICA) had decided to help Pakistan through a project for developing lesson plans and establishing a model for science teachers training. This paper aims to highlight the project activities and analyze the impact of baseline and end-line surveys in terms of its inputs and achievements during three years project (2009-2012). This includes the preparation of science lesson plans, training of master trainers, training of school science teachers, school cluster programs and organizing awareness seminars at the Federal and the Provincial levels that helped in development and continuity of science efforts being made for the implementation of science curriculum in Pakistan. Four instruments and an observation sheet were used for data collection. The data of the study is represented through graphs and a statistical examination is carried out in terms of difference-in-difference estimation. The findings of the study can be linked with implications of SCIB project on standards of science curriculum in Pakistan. The recommendation of the study underpin for improvement in identifying alternate strategies and the options for a more effective and efficient in-service teacher education model. The results of the study may help in exploring the possibilities of sharing and generating cross-cultural studies and projects in science education among other countries.

Keywords: Student centered, Inquiry based, Standards, Science curriculum

## A low cost approach to the integration of IT into physics education

Alexandr I. Fishman

Kazan Federal University, Institute of Physics, Russia

Email: aif@ksu.ru

Andrey I. Skvortzov

Kazan Federal University, Institute of Physics, Russia

Email: anivskvor@gmail.com

Abstract: Modern computer technologies potentially give the teacher unique tools for organizing experimental research activities, and for the creation of new interesting physical problems. Two educational multimedia recourses: "*Video book of physical problems*"(VB) and "*Telemetric practical work in physics*” (TPW) are described in this paper. The principle … “To see once is better than to hear a hundred times.” is the central premise in the design of VB. The physics questions in VB are formulated in a novel way: students first look at the video clips in which the different experiments are shown. Then they are asked to find answers to questions by analyzing the video and sound information that they have observed. In TPW a real physical experiment is recorded on video. This video file is given to students. Using special software, they can measure position coordinates of the bodies, angles, light intensity, sound levels and times directly on the frames. The results can be analysed and presented in tables and graphs. VB and TPW improve the efficiency of e-learning in physics.

Keywords: computer technologies, telemetric, video problem, physics education, e-learning

## Students’ Perception on their Science Teachers’ Pedagogical Content Knowledge

Lilia Halim

Faculty of Education, Unversiti Kebangsaan Malaysia

Email: lilia@ukm.my

Sharifah Intan Sharina Syed Abdullah

Faculty of Education, Unversiti Kebangsaan Malaysia

Email: sharifah.intan.sharina@gmail.com

T. Subahan Mohd Meerah

Centre of Educational Development, Universiti Kebangsaan Malaysia

Email: subhan@ukm.my

Abstract: Pedagogical content knowledge (PCK) is a type of teacher knowledge to be developed by a teacher and PCK is said to contribute to effective teaching. Most studies investigated the development of PCK and its influence on students’ learning from the teachers’ perspectives. Lack of studies has looked from the students’ perspectives of what components of science teachers’ PCK that helped their learning. Thus it is the aim of this study to investigate the level of science teachers’ pedagogical content knowledge from students’ perspective, in particular whether students of different ability had different view of teachers’ PCK in assisting their learning and understanding. Based on the PCK literature, six components of PCK has been identified, which were: (i) subject matter knowledge, (ii) knowledge of teaching strategies, (iii) knowledge of concept representational, (iv) knowledge of teaching context, (v) knowledge of students’ understanding, and (vi) knowledge of teaching evaluation. 56 Likert’s scale items were used for data collection from 316 Form 4 students (16 years old). One way ANOVA analysis revealed that there was statistical significance found at p=0.004 of science teachers’ PCK for students of different ability. Overall, students of various academic abilities view all the components of PCK as important. However, the low ability students view less important on all the components of PCK compared to the high and moderate achievers. In particular, low ability students do not view ‘Knowledge of Concept Representational’ as important for effective teaching. On the other hand, they value the fact that teachers should be alert to their needs, such as sensitive to students’ reaction and preparing additional learning materials. This study reveals that PCK of science teachers need to differ for high and low ability students.

Keywords: Pedagogical content knowledge, science teaching, secondary students

## A Long-Term Student Teaching Program in Promoting Practical Knowledge for Pre-Service Science Teachers

Koichi Furuya

Hokkaido University of Education, Japan

Email: furuya.koichi@a.hokkyodai.ac.jp

Abstract: Five weeks of student teaching is required to obtain a science-teaching certificate of secondary school in Japan. However, this period is shorter than that required in the United States, Finland, and China. The purpose of this study is to investigate whether long-term student teaching (LTST) is effective in helping pre-service teachers (PSTs) develop the practical knowledge required as a science teacher. We conducted a yearlong student teaching program; during this period, PSTs were given several sessions of lesson study, in which they learned how to give a science class. To measure the effectiveness of LTST program, we compared the practical knowledge of the LSTS group to that of the short-term student teaching (STST) group in observing a video of a lesson presented as an example (video case). Using the terminology developed by Sato et al in 1990, we examined the PSTs’ on-line (i.e., thinking aloud) and off-line (i.e., writing a report) responses in both groups. The PSTs in the LTST group spoke 2.4 times as many words in thinking aloud sessions than the PSTs in the STST group. The difference observed among PSTs in the thinking aloud components of the LTST and STST programs was due to differences in the PSTs’ focusing on children’s learning. Whereas PSTs in the STST program only focused on teaching: how the teacher taught the content, PSTs in the LTST group focused on not only teaching but also how students learned and what might make it difficult for students to learn the content. After the PSTs observed a video case, PSTs in the LTST group viewed the lesson in a way that resembled a storyline, as they expressed in their written reports. The attention paid to students’ learning and the storyline of the lesson can be attributed to a teacher’s practical knowledge. Therefore, it was found that LTST promotes practical knowledge among PSTs.

Keywords: long-term student teaching, practical knowledge, PCK, science teaching, lesson study, pre-service teachers

## Suggesting a Flow Map of the Nature of Science based on Kuhn’s Scientific Revolution for Sciences Education

Jun-Young Oh

Hanyang University, Seoul, Republic of Korea

Jyoh3324@hanyang.ac.kr

Abstract: The purpose of this study is to develop the flow map of History of Science (HOS) instruction on students learning of Nature of Science (NOS) and Science Content Knowledge (SCK) in order to enhance students overall scientific literacy. The NOS aspects have been emphasized in recent science education reform documents as disagreeing with the received views of common science. It is valuable to introduce students at the elementary level to some of the ideas developed by Kuhn. The key aspects of the nature of science (based on Lederman, et al., 2002) and history of science through Kuhn’s philosophy are good applications to Copernicus Revolution, the one of main accidents of the history of Astronomical Science. Therefore a NOS Flow Maps could be a promising NOS tenets understanding and an explicit and reflective tool to enhance science teaching and learning for science teachers. In research I suggest that we should have a teaching the knowledge of HPS in our science teachers’ programs.

Keywords: History of Science, Nature of Science, Science Content Knowledge, Philosophy of Science, Kuhn’s philosophy, Copernicus Revolution

## Fostering conceptual change in Chemistry: Experiences from a pre-service teacher education program in Singapore

R. Subramaniam

National Institute of Education, Nanyang Technological University, Singapore

Email: subramaniam.r@nie.edu.sg

Abstract: In the teaching of chemistry at secondary level, a common problem faced by chemistry teachers is the alternative conceptions harbored by students. These conceptions are at variance with the scientifically correct conceptions and therefore interfere with learning. When these incorrect conceptions are not remediated, they also pose barriers to promoting functional understanding. One of the reasons why school teachers are not well equipped to address alternative conceptions harbored by students in chemistry is that they have not been exposed to the various strategies used to identify alternative conceptions as well as how to address these using a range of conceptual change strategies. In this regard, the National Institute of Education in Singapore recently introduced a program on remediating alternative conceptions in various topics in chemistry for its pre-service chemistry teachers. Special features of the program include an overview of conceptual change theories; approaches such as analogies, demonstrations, simulations, refutation texts, targeted teaching and cooperative learning to address alternative conceptions; examples of these approaches to address alternative conceptions in various topics in chemistry; and assessment strategies to decide whether conceptual change has occurred. As part of the assessment, a tutorial requiring students to identify an alternative conception and show to their peers how it can be addressed using any of the stated approaches is set; a unique feature of the tutorial is the feedback given not only by the course instructor during the session but also by their peers in a blog after they have uploaded their presentation materials. The latter ensures that the presentation materials would be available for use by others. This study elaborates on the above program and documents the pre-service teachers’ experiences in the foregoing program. As part of the latter, a psychometrically robust survey form was designed to elicit feedback. Statistical analyses of the data from the survey form are also presented. Feedback from pre-service teachers on the program is very positive. Some implications of the study in respect of teaching and learning as well as the professional development of chemistry teachers are also discussed.

## The Development of POCoM (Practical On-site Cooperation Model) for Korean Science Teacher Profession with the approach of PAR (Participatory Action Research)

Young-Shin Park

Chosun University, Republic of Korea

parkys@chosun.ac.kr

Jongwon Park

Chonnam National University, Republic of Korea

Youngmin Kim

Pusan National University, Republic of Korea

Jongseok Park

Kyungbook National University, Republic of Korea

Jinsu Jeong

Daegu University, Republic of Korea

Abstract：In Korea, there are three different teacher preparation institutes, where preservice are taking courses including general science and liberal arts courses mainly at fresh and sophomore and general education as well as specific science major at junior and senior. After then, they are qualified to take National Teachers Evaluation Test (NTET) to be passed and assigned to one of public schools. Once science teacher candidates are appointed at public schools to teach science subject, they are required to take Professional Development Programs (PDP) afterwards. However, we have been still focusing on how to improve science teachers' teaching envisioned in *Standards* (2000) despite teachers had taken the structured teacher preparation program as well as enough PDPs for their profession. The problem is that Korean science teachers are well equipped with new and current theories mainly, not to be bridged into practices of classroom teaching. Science teachers seem not to promote their teaching strategies no matter what PDP they take. Teachers do not have chances of implementing what they have learned after taking PDPs. What is worse, they do not have any partner to evaluate their implementation to see how much teachers are improved in teaching. For the valid system where teachers become profession in their science teaching, they need to actively '*reflect*' on their theories and practices through the *'action'* of questioning, thinking, and contextualizing and reforming them in the context-bound action and through another *'action'* of collaborating with other experts in the social-bound interaction, which we name ‘participatory action research’ (PAR). The goal of this study is to help secondary science teachers to improve teaching by bridging theory into practice with the use of POCoM (Practical On-site Cooperation Model) where researchers as experts analyzed science classes using the observational checklist and discussed what to improve. Then, teachers tried to improve teaching in another classroom with the same content according to agreement between research and teacher. This cyclic collaboration continued up to 4 times for one week. Through the POCoM, much improvement in science teaching was noticed quantitatively as well as qualitatively.

## New Structure of New Curriculum in China’s Non-key Senior High Schools in This Century[[1]](#footnote-1)

Boqin Liao

The Research Center of Science Education of Southwest University, Chongqing, China

Email: bqliao@swu.edu.cn

Abstract: This paper introduces the new structure employing in the new curriculum in the new round Curriculum Reform. The table in this paper shows the learning areas, subject matter and modules in the new structure. And the illustrations aim at explicating Physics course structure and the integration of the different modules to educate students.

Keywords: Curriculum Reform; Non-key Senior High School; Curriculum Structure

## An Experimental Study on Integrated Model of the Application of Computer Simulation to Scientific Discovery Learning in Middle School Physics

Taihua Li

School of Electronic and Information Engineering, Southwest University, Chongqing, China

Email: litaihua@gmail.com

Lingmin Yuan

The Research Center of Science Education of Southwest University, Chongqing, China

Email:yuanlingmin2007@163.com

Boqin Liao

The Research Center of Science Education of Southwest University, Chongqing, China

Email: bqliao@swu.edu.cn

Abstract: Computer simulation can offer an open exploring learning environment for the learners, therefore, is usually considered as an instrument for the scientific discovery learning. Based upon the present researches, we analyzed the activity structure of scientific discovery learning. Moreover, based upon the teaching situation and the earlier investigation, we placed computer simulation as an experimenting and exploring aspect for the scientific discovery learning to offer an environment of experimenting and exploring for the students. Grounded upon the experimental study of the basic model of the application of computer simulation to scientific discovery learning, we designed an integrated model. Compared with the scientific discovery learning model that is based upon the real-life experience, the results show that: 1) The integrate model of the application of computer simulation into scientific discovery learning shows very significant promoting effects upon the students’ mastery of the principle knowledge; 2) The integrate model of the application of computer simulation into scientific discovery learning shows no significant promoting effects upon the students’ intuitional understanding; 3) The integrate model of the application of computer simulation into scientific discovery learning shows significant promoting effects upon the students’ ability of the flexible application of the knowledge; 4) The students’ physics basis has very significant effects upon their scientific discovery learning; 5)The integrate situation model basically realizes the complementary advantages between computer simulation situation experiments and the real-life experiences, but it exposes some drawbacks in the aspect of students’ understanding of the nature of experiment exploring and students’ changing of naive conceptions.

Keywords: computer simulation, scientific discovery learning, Modes of the Application, middle school physics

## On the Evolution of a Lesson: Group Preparation for Teaching Contest as Teacher Professional Development Activity for Chinese Elementary Science Teachers

Xiaowei Tang

Xiaowei.tang@gmail.com

Faxian Shao

shaofaxian@qq.com

Abstract: Teaching contest is a type of teacher professional development activity unique to China. Through participant observation and discourse analysis of a typical case, this study explored how elementary science teachers negotiate practical understandings of science teaching during the lesson-polishing process. Guided by the framework of practical rationalities (Herbst & Chazan, 2002), we identified three types of practical suggestions in terms of their operational dimensions and nine categories of dispositions in terms of their foci of attention. The study found that the distribution of dispositions and practical suggestions vary through out the lesson polishing process. When practices stemming from different dispositions run into conflicts, traditional norms and power relationships often dominated, determining how the tradeoffs should be made. The advantages and drawbacks of lesson-polishing as a professional development approach for science teachers have been discussed by the end.

Keywords: professional development, lesson polishing, practical rationalities

## An Empirical Study of Influence Factors of Elementary Science Teachers’ Professional Development Level

SHOU Xin

College of Chemistry, Chongqing Normal University, China

LIN Changchun

Primary Teacher Education Research Center, Chongqing Normal University, China

Abstract: Based onconducting a questionnaire survey ,using hierarchical linear modeling, the paper is to empirically investigate the influence factors of Level of elementary school science teachers' professional development at the individual level and school level. The study found that teacher seniority, academic diplomas, job title, are the three main individual factors that influence the professional development of science teacher. School plays a key role to motivate the level of the professional development of science teacher, there are great school distinctions among the level of the professional development of science teacher, school differences are one factor which caused science teachers’ professional development existing uneven. School's teacher evaluation mechanism, provided the opportunity for teachers’ development by school, [teacher](http://dict.youdao.com/w/teacher/) [training](http://dict.youdao.com/search?q=training&keyfrom=E2Ctranslation) are also some important factors which caused science teachers’ professional development exist uneven. So as to narrow the differences in the levels of the professional development of science teachers, developing of multi-evaluation mechanism, carrying out school-based teaching and research, further improving the training of science teachers are some [measures](http://dict.youdao.com/search?q=measures&keyfrom=E2Ctranslation) to strengthen the ranks of science teachers.

Key words: primary school science teacher; professional development; hierarchical linear model; Empirical research

# Public Science Education

## Search for SEAMEO Young Scientists (SSYS) – RECSAM’s Initiative for Promoting Public Science Education: The Way Forward

Dominador Dizon Mangao

SEAMEO RECSAM, Penang, Malaysia

dominador\_mangao@recsam.edu.my

Ng Khar Thoe

SEAMEO RECSAM, Penang, Malaysia

nkt@recsam.edu.my

Abstract: Every government strives to equip its citizens with scientific and technological literacy to meet the challenges of 21st century. SEAMEO RECSAM is a regional centre mandated to enhance science and mathematics education in the Southeast Asian region. RECSAM organizes the Search for SEAMEO Young Scientists (SSYS) Congress, dubbed as the INTEL International Science and Engineering Fair (ISEF) version in Southeast Asia. This innovative intervention nurtures the development of scientific thinking and 21st century skills as students engaged in research projects on authentic community problems. This paper reports on three case studies from Thailand, Philippines and Malaysia. The first and second cases elaborated on SSYS as a bridge for formal and informal science education. The third case dealt with RECSAM’s e-portal called “Southeast Asia Regional Capacity–Enhancement Hub (SEARCH),” an initiative for public access to science education and at the same as resources for science teaching and learning. In conclusion, SSYS initiative needs to be strengthened by the Ministries of Education of 11 SEAMEO member counties to ensure more participation among young scientists and wider public access to informal science education for the promotion of scientific literacy in the region. Educational implications and future directions are also advanced.

Keywords: science congress, youth research projects, informal science education, public science education

## The Tentativeness of Scientific Theories: A study of views from different educational levels in Malaysia

Jasmine Jain

Faculty of Education, Universiti Teknologi MARA Malaysia

Email: jasmynjain@gmail.com

Nabilah Abdullah

Faculty of Education, Universiti Teknologi MARA Malaysia

Email: nabil789@salam.uitm.edu.my

Beh Kian Lim

Faculty of Education, Universiti Teknologi MARA Malaysia

Email: behki363@salam.uitm.edu.my

Abstract: Developing science literacy has been the perennial aim of science education. One suggestion to achieve this literacy would be to ensure students have sound understanding of the Nature of Science (NOS). This is because comprehending NOS develops eloquent learners in science-based decision making, resulting in better scientific literacy (Parker, Krockover, Lashertrapp & Eichinger, 2008). This study examined the views of NOS among students across different educational levels in Malaysia, focusing solely on an aspect of NOS- The tentativeness of scientific theories. This study was qualitatively designed, where a semi structured interview protocol adapted from VNOS-C (Lederman, Abd-El-Khalick, Bell, & Schwartz, 2002) was used. The educational levels were namely lower secondary, upper secondary and post matriculation levels; with nine respondents interviewed individually for each level using the phenomenographic approach. From the data analyzed, it was found that the students' views of theory can be categorized into four, namely "static", "book static", "conditionally tentative", and "tentative". The categories revealed different categories on the way Malaysian students perceived the nature of scientific theories compared to their counterparts in other countries.

Keywords: Nature of Science, Scientific literacy, Tentativeness

## The Study of Docent System Improvement for the Popularizaton of Science in Korea

Young-Shin Park

Chosun University, Republic of Korea

parkys@chosun.ac.kr

Abstract: The Study of Docent System Improvement for the Popularizaton of Science in Korea The number of science museums in Korea as well as other countries is increasing and with this comes the demand for engaging and even entertaining educational programming recently. To meet the goal for this, science museum call on volunteers to serve as docents and interpreters of objects and exhibits. It is also indicated that the revitalization of science museum depends on the number of qualified docents who can meet the museum visitors’ educational needs. However, the current unstructured docent system is not sufficient to meet the goal. Forty six docents currently working in science museums were surveyed about docent training program, current working conditions, and docent professional program in order to propose a viable system providing a docent profession. Data were collected through surveys with 46 docents, interviews with two experienced docents, and several artifacts from the science museum and selected docents. The surveys consisted of 47 items asking about personal biography, docent’s perception, docents training program they took, current working conditions, and supplementary professional program. Docents believed that they are more than “administrative volunteers” in the center. They also displayed perception that it is very pivotal to interact with curators or program developers as well as other docents to run docent system effectively. Docents indicated that there must be structured docent training/professional program where they could learn pedagogy skills as well as subject matter necessary in interacting with visitors. The conclusion of this study is as follows; First, there must be recognition about docents who can play educator’s roles different from those of administrative volunteers from the point of recruiting and training system in science museum. Second, docents need to take training and supplementary professional courses that focus on observing experience docents and real context of educating visitors. Third, we need a well-structured evaluating tool for the structured docent system. A well-established docent system will bring forth the enhancement of science museum education and the increase of science popularization by providing visitors with the quality educational services.

## The Study of Koreans’ View of Nature

Yumi Lee

Chongryang Elementary School

Email: krmutine@nate.com

Yeon-A Son

Dankook University

Email: [yeona@dankook.ac.kr](mailto:yeona@dankook.ac.kr)

Abstract: Science is an activity based on the wonders of what happens in nature. The process of theorizing and organizing natural phenomena are affected by views of nature. Koreans’ view of nature was discussed by analyzing literature, mythology, folk tales, and proverbs. Korea was originally agrarian, and therefore its understanding of nature is cyclical and organic. They recognize humans as a part of nature rather than the controller of nature. Rapid and severe changes in the natural environment created a feeling of awe of nature for Koreans which emphasize humans being as one with natural. Shamans’ myths and narrative literature show an evolving view of creation and pantheistic belief. Today in Korea, the mainstream of school science education is based on western modern science. It is required to recompose science curriculum, textbooks and teaching-learning strategy which reflect on Koreans’ view of nature.

Keywords: view of nature, meaning of nature, Koreans’ view of nature

## Evaluative Thinking in the Building of Learning Society

Nian Zheng

China Research Institute for Science Popularization, China

nzhjx@yahoo.com.cn

Limei Zhang

Science Popular Press, China

zhlmlm@126.com

Huijun Zhang

China Research Institute for Science Popularization, China

286388044@qq.com

Abstract: Traditionally, China is a nation, in which people likes learning the sages' theories, lessons and knowledge that handed down from one generation to another. In modern society, learning is more and more important for the civilization and modernization of the nation, thus Chinese government and leaders have been calling for building a learning society and an innovative country since the beginning of a new century. But how to get this goal, as the authors' argument, is a more important issue and need to study further. They proposed that evaluation is a good way to build a learning society, and evaluative thinking could play the main role in the process of building an innovation country.

Keywords: learning society, evaluative thinking, capacity building, innovation

# Other Topics

## Laboratory-Based Scaffolding Strategies for Learning School Science

Au Sau Kheng

National Institute of Education, Singapore

au\_sau\_kheng@moe.gov.sg

Tan Kok Siang

National Institute of Education, Singapore

koksiang.tan @ nie.edu.sg

Abstract: The social cultural theory and concept of zone of proximal development (ZPD) of Lev Vygotsky are often referred to as the theoretical underpinnings of scaffolding (Stone, 1998; Davis, 2004; Pea, 2004). Under Vygotsky’s influence, an in-depth empirical study was done on scaffolding processes by Wood, Brunner and Ross. Wood and co-workers (1976) coined the term ‘scaffolding’ to describe the support a learner received to achieve specific goals that would otherwise be beyond his or her independent reach. Since the introduction of this metaphor 35 years ago, it has been widely used and adapted for educational contexts. This construct has been applied frequently, practiced broadly and generalized by educators and researchers for classroom practices and studies. Since then, the term ‘scaffolding’ has also been re-defined and re-interpreted in various ways but the main idea of it being a form of support for learners attempting to achieve specific learning goals under a wide range of learning environments remains unchanged. This paper presents a recent study in Singapore on the use of scaffolds in a school science laboratory setting. It will examine research studies on the various support strategies, materials and tools used in various learning environments and goals that may also be appropriately used in the learning of school science, especially while learners are engaged in performing science experimental tasks in a laboratory setting. The paper will include a sharing of the various laboratory-based scaffolding structures used in the study to help students do and learn science through hands-on experimental tasks. The recommendations on how students’ competencies in school experimental science can be enhanced through scaffolds (and the gradual weaning of these) will be useful to science teachers, educators and educational researchers looking at ways to improve students’ achievements in school science.

Keywords: scaffolding, metaphor, support, tools, fade

## Students’ Understanding of Light Propagation and Visibility of Objects in Different Contexts; Stable or Unstable Conceptualization

Hye-Eun Chu

Nanyang Technological University, Singapore

Email: [hyeeun.chu@gmail.com](mailto:hyeeun.chu@gmail.com)

David F Treagust

Curtin University, Australia

Email: [d.treagust@curtin.edu.au](mailto:d.treagust@curtin.edu.au)

Abstract: This study focuses on elucidating and explaining reasons for the stability of and interrelationships between students’ conceptions about Light Propagation and Visibility of Objects in different contexts across three years of secondary schooling, from Years 7 to 9. It is a large scale quantitative study involving 1,233 Korean students and 1,149 Singapore students. Data was collected using a questionnaire called the Light Propagation Diagnostic Instrument (LPDI). This tested students’ understanding of two conceptual groups, using four pairs of questions, each of which evaluated the same concept in two different contexts. Findings show that students generally could not apply their conceptions of basic optics in different contexts, giving rise to several context-dependent alternative conceptions. Also, students had a more stable understanding of Light Propagation concepts compared with their Visibility of Objects concepts, which required a more sophisticated understanding of the behaviour of light in different contexts. The students’ concepts of Light Propagation and Visibility of Objects were only moderately correlated. This moderate correlation between these two concepts can be one reason why the students showed different understanding patterns with regard to the concepts of Light Propagation and Visibility of Objects. While school grades were not a strongly effective variable, students’ school achievement influenced their conceptual understanding of optics strongly. Also, the different teaching and learning approaches and education systems in the two countries influenced the students’ conceptual understanding. The research findings imply that the students should have more opportunities to discuss scientific concepts and their application in different contexts. Further research is needed to observe the students’ development of their conceptualization related to the concepts of Light Propagation and Visibility of Objects in different contexts.

Keywords: optics concepts, stable alternative conceptions, unstable alternative conceptions

## Exploration of high school students’ concepts about climate change through the use of an Issue Concept-map (IC-map)

Kongju Mun

Ewha Womans University, Republic of Korea

Email: mkj@ewha.ac.kr

Jinhee Kim

Ewha Womans University, Republic of Korea

Email: kkjjeneb@hotmail.com

Sung-Won Kim

Ewha Womans University, Republic of Korea

Email: sungwon@ewha.ac.kr

Joseph Krajcik

Michigan State University, USA

Email: krajcik@msu.edu

Abstract: In this study, we explored high school students’ concepts related to climate change. A total of 155 high school students participated in the study. The researchers developed an Issue Concept-map (IC-map) to evaluate the students’ personal concept understanding. The IC-map is a structured concept-map that is designed to explore students’ understanding of various issues. The accompanying worksheet is organized by context (personal, societal, and global) and occurrence (cause, influence, and countermeasure). The IC-map allows students to freely express their ideas on the causes, phenomena, and countermeasures of climate change on a personal, societal, and global level. Students completed the IC-map worksheets individually to express what they knew about climate change. We coded all 3,570 words or sentences and then classified and categorized them. We also identified patterns on the basis of connections among students’ concepts on the IC-maps. We discovered 224 concepts on climate change that could be separated into 63 categories. We also found that there were misunderstandings and misconceptions about climate change among the students. One particularly important misconception was that some students confused climate change with global warming and ozone layer depletion. The IC-map allowed students to express their ideas and make connections between concepts. We suggest that educators and researchers who develop science education materials need to consider students’ conceptual understanding of climate change. We also suggest that researchers and science educators continue to work with students to gain an in-depth understanding of their knowledge of socio-scientific issues such as climate change.

Keywords: climate change, concept map, issue concept map, global warming, concept understanding

## Energy education curriculum for children based on fostering creativity in elementary school

Rasol Abdullah mirzaie

ra.mirzaei@srttu.edu ;

Shahid Rajaee Teacher Training University , Iran

Neda Zerafatdoost

[n.zerafatdust@yahoo.com](mailto:n.zerafatdust@yahoo.com) ,

Shahid Rajaee Teacher Training University , IRAN

Abstract: Energy is a subject that is taught to children in elementary school. One of the concepts of science education in primary school is energy. Energy is subject that children are familiar with in their daily lives. Children are familiar with energy resources and consumption in everyday life. They also are realizing the importance of energy in their daily lives. Some children's beliefs about the energy are: Some things are working with electricity. Energy is necessary for the human body. If energy is not a man cannot do its job. We eat food to obtain energy. Energy sources are high. We must save our electrical energy consumption. In Iran, in the third year in elementary school on the introduction of energy and resources and energy consumption is emphasized. In science education, various methods were used for involving students in learning process. Hoverer, it is very important how we can introduce especial subject to children. For gaining more cognition about importance of energy and manner of consumption, this concept was taught in science class at third grade elementary school. For this purpose, science activity based on creativity was designed. In prepared pattern, students were involved by practical work. The learners were active in learning process and discussed to each other in groups. For evaluation designed pattern, 50 third grade school students were selected in two groups (experimental and control groups). For investigation learning process, achievement and creativity Torrance tests in pre and post form were used. Our results showed the effectiveness of introduced teaching pattern for learning energy concept in elementary school. It will be discussed more in this paper.

Keywords: science; elementary school; creativity; third grade; energy education

## Argumentation in university chemistry education: A case study of practical investigations from Activity Theory perspective

Xiaomei Yan

Graduate School of Education, University of Bristol

Email: x.yan@bristol.ac.uk

Abstract: Argumentation has attracted attentions in science education for over 2 decades. In this study, I proposed to explore argumentation in a specific context, the chemistry practical course in the university. The tertiary chemistry students have been widely acknowledged their challenges in coordinating theoretical knowledge presented in lectures and empirical data gathered through experimentation in laboratory contexts. Therefore, argumentation as a key strategy in linking theory and evidence would be explored in the empirical study of this context. Taken the complex learning environment into considerations, this study has employed the Activity theory as an theoretical framework to reveal the role of argumentation in the 2nd year chemistry practical course in one university in UK. The data collected from different sources (including the students, the demonstrators and the academic tutors) by various methods (such as the individual interviews, the observations and the collected students' experiment reports) indicated argumentation has been regarded as an necessary scientific skills to acquire instead of as a tool for learning, which was advocated by the researchers and educators. Moreover, the different features of students' oral arguments in the laboratory and written arguments in the experiment reports have been attributed to the implicit and explicit instructional context for these two tasks.

Keywords: argumentation, activity theory, tertiary chemistry education, practical education

# Poster

## Exploring connections between inquiry science teaching and language development for English Language Learner (ELL) students using observation analysis and cogenerative dialogue

Jennifer C. Park

Seoul National University

jennifercpark2@gmail.com

Sonya N. Martin

Seoul National University

sm655@snu.ac.kr

Abstract: This study examines a grant-funded model used to support urban science teachers to effectively teach English Language Learner students in inclusive settings. The model incorporates observations using the SIOP and RTOP instruments and the use of cogenerative dialogues with teachers, K-12 students, and researchers.

Keywords: English Language Learner, RTOP, SIOP, Cogenerative dialogue

Structure of the Student Interest in Science and Scientific Literacy: Using the Latent Class Analysis

Takuya Matsuura

Graduate School of Education, Hiroshima University

Email: takuyam@hiroshima-u.ac.jp

Abstract: This study explore the latent class of the structure that analyzes Japanese students’ interest in science and scientific literacy based on the result of PISA2006. As the result of this analysis, Japanese students divided two latent classes that differ from the direct effect of instrumental motivation to learn science (F6) to scientific literacy (F7).

Keywords: PISA2006, Scientific Literacy, Latent Class, Interest in Science

## Effects of Different Contexts on Lower Secondary School Students’ Scientific Reasoning

Hiroshi Unzai

Graduate School of Education, Hiroshima University

Email: hiroshi-unzai@hiroshima-u.ac.jp

Abstract: This study aimed to explore the relationship between process of thinking in scientific reasoning and contexts among Japanese lower secondary students. As a result, I found that a way of the dependence on form of context varied according to process of thinking in scientific reasoning.

Keywords: Scientific Reasoning, Lower Secondary, Context, Japanese Student

## Argumentation in tertiary chemistry education: Field- dependent students' written arguments in UK and China

Keping Sun

Shanghai Normal University, China

Email: kepings@shnu.edu.cn

Xiaomei Yan

University of Bristol, UK

Email: x.yan@bristol.ac.uk

Abstract: Recent year, argumentation has been attracting increasing attention from educators and researchers in science education. However, during the practice of implementing argumentation into science classrooms, the educators and researchers identified the factors from the learning environment which would affect the students' performance of argumentation. It advocates further research in context-specific argumentation, in terms of both discipline-specific features of argumentation and the culture and historical context of learning environment where argumentation took place. Therefore, we aim to extend the research literature of argumentation into tertiary chemistry education and particular culture contexts in UK and China. In particular, we have focused on analysing the features of students' written arguments based on their experiment reports.We would like to shed light on how different culture and learning contexts shape the features of the students’ arguments produced in the chemistry practical courses. Moreover, we also questioned the dominated western philosophy traditions in analysis of arguments and suggestions for instructional strategies.

Keywords: argumentation, experiment reports, tertiary chemistry education

## Case study of the development process of outstanding prospective science teacher

Xiaoxin Lv

Department of Teacher Education, Nanjing Xiaozhuang University, China

Kai Chen

Department of Teacher Education, Nanjing Xiaozhuang University, China

Bo Chen

Faculty of Education,University of Macau

Abstract：The study aimed to investigate the development process of outstanding prospective teachers. W and L, who are now authorized teachers in different primary schools, were invited as participants. Interviews and observations, made under natural state, about their development process, were recorded and analyzed. It was found that the development process of outstanding prospective science teachers experienced three stages——confused period, excited period and pursuing period, and the main factors which promoted the growth of prospective science teachers included instructor, teaching experience out of school and individual attitude.

Key words: case study, development process, outstanding prospective science teacher, main factors

## The International Baccalaureate Diploma Science programme

David Jones

The International Baccalaureate Organization

david.jones@ibo.org

Abstract: Description of The International Baccalaureate® (IB) as a high quality program of international education to a worldwide community of schools, the IB Diploma program as a 16-19 years program for university entrance, with a particular focus on group 4, the science courses of the Diploma program, Physics, Chemistry and Biology (also briefly, the other group 4 subjects - Environmental Systems and Societies, Sports, Exercise and Health Science, Computer Science and Design Technology.)  This will include the course structures, the curriculum and assessment models and subject content. Details of the assessment, both internal and external examinations will be given and novel features of the course emphasized. There will also be an introduction to a new science course being developed and how curriculum development in general is undertaken in the IB diploma programme. For each of the above there will be references to issues and challenges to the IB.

Keywords: International Baccalaureate, diploma program, science courses, high stakes, criterion referenced

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