Baohui Zhang · Gavin W. Fulmer
Xiufeng Liu · Weiping Hu
Shujin Peng · Bing Wei *Editors*

International Conference on Science Education 2012 Proceedings

Science Education: Policies and Social Responsibilities

Springer

International Conference on Science Education 2012 Proceedings

Baohui Zhang • Gavin W. Fulmer • Xiufeng Liu
Weiping Hu • Shujin Peng • Bing Wei
Editors

International Conference on Science Education 2012 Proceedings

Science Education: Policies and Social Responsibilities

Springer

Editors
Baohui Zhang
Institute of Education
Nanjing University
Nanjing, Jiangsu, China

Gavin W. Fulmer
National Institute of Education
Nanyang Technological University
Singapore, Singapore

Xiufeng Liu
Graduate School of Education
University at Buffalo
NY, USA

Weiping Hu
Teacher Education
Shaanxi Normal University
Xi'an, China

Shujin Peng
Department of Scientific Research
Sichuan Normal University
Chengdu, China

Bing Wei
Faculty of Education
University of Macau
Macau, China

ISBN 978-3-642-54364-7 ISBN 978-3-642-54365-4 (eBook)
DOI 10.1007/978-3-642-54365-4
Springer Heidelberg New York Dordrecht London

Library of Congress Control Number: 2014939025

Printed on acid-free paper

Springer is part of Springer Science+Business Media (www.springer.com)

Organization

Organizers

National Association for Science Education the Chinese Society of Education (CNASE), China

Institute of Education, Nanjing University, China

Co-organizers

Institute of Chemistry Education, Beijing Normal University, China

Center for Teacher Professional Ability Development, Shaanxi Normal University, China

China Research Institute for Science Popularization,

Center for School Curriculum Research & Development Research, Institute of Science Education, Guangxi Normal University, China

Sponsors

Shandong Yuanda Net & Multimedia Ltd., China

Springer Verlag

Popular Science Press, China

China Science and Technology Press, China

About the Chinese Science Education Association

The Chinese National Association for Science Education (中国教育学会科学教育分会, CNASE, http://www.cnase.org) is a branch of the Chinese Society of Education (CSE). The Chinese Society of Education (CSE, http://www.cse.edu.cn) was founded on April 12, 1979. It is the first and largest national organization for mass educational academic affairs. CSE has 49 branches. The CNASE, as one of the branches, was founded in November 2009. It has three subcommittees at K–6, G7–12, and college levels, respectively. This is the national association of Chinese science educators, science education researchers, and other related scholars and administrators.

About Nanjing University

Nanjing University (http://www.nju.edu.cn) is one of the oldest and most prestigious institutions of higher learning in China. On May 20, 2012, the university has celebrated its 110th anniversary. In 2011, QS World University Rankings ranked Nanjing University 186th overall in the world. It is one of China's key comprehensive universities under the direct supervision of the Ministry of Education. It dates from 1902 when it was known as Sanjiang Normal School. Today's NJU consists of three beautiful campuses, Gulou, Pukou, and Xianlin.

About the Institute of Education, Nanjing University

The Institute of Education of Nanjing University (http://edu.nju.edu.cn) was set up at the end of 2009. It was built up on the bases of earlier Institute of Higher Education (1984–2002) and later Department of Educational Sciences and Administration (2002–2009), let alone its ancestor dated back as early as to the founding period of Nanjing University at the beginning of the twentieth century. Currently, there are 19 staff members in this institute, among them are 17 full-time academic faculties. Research areas and interests of the faculty include education administration and policies, curriculum and instruction studies at both K–12 and college levels, educational technology and learning sciences, educational sociology (especially regarding educational equity), student learning and development, cross-cultural studies in educational internationalization, history of education, and science education. There are four M.A. programs, two Ph.D. programs, and one Ed.D. program in this institute. The total enrolment of research students is around 130. The Institute of Education also hosts an academic quarterly journal: Higher Education Exploration and Research (in Chinese).

Conference Organization

International Organizing Committee

Prof. Shujin Peng, Cochair
Department of Scientific Research,
Sichuan Normal University,
Chengdu, China

Prof. Xiufeng Liu, Cochair
Graduate School of Education,
University at Buffalo, NY, USA

Prof. Young-Shin Park
Chosun University, Korea

Prof. Takuya Matsuura, Hiroshima
University, Japan

Prof. Subramaniam Ramanathan
Nanyang Technological University,
Singapore

Dr. Gavin W. Fulmer
National Institute of Education,
Singapore

Prof. Bilal Gunes
Gazi University, Turkey

Dr. Mustafa Sozbilir
Ataturk University, Turkey

Prof. Sibel. Erduran
University of Bristol, UK

Dr. Anil Banerjee
Columbus State University, USA (India)

Prof. Alexander Fishman
Kazan State University, Russia

Prof. David Treagust
Curtin University, Australia

Dr. Ling L. Liang
La Salle University, USA

Prof. Lilia Halim
National University of Malaysia,
Malaysia

Dr. Rasool Abdullah Mirzaie
Shahid Rajaee Teacher Training
University, Iran

Ms. Beverley Cooper
the University of Waikato, New Zealand

Dr. Alyas Qadeer Tahir
Director, National Institute of Science
and Technical Education, Islamabad,
Pakistan

Prof. Christiane Gioppo
Universidade Federal do Parana (UFPR), Regional Representative for Latin America, ICASE, Brazil

Dr. Ben Akpan
International Council of Associations for Science Education (ICASE) president, Nigeria

Prof. Winnie So
Hong Kong Institute of Education, Hong Kong

Prof. Hsin-Kai Wu
National Taiwan Normal University, Taiwan, China

Prof. Mei-Hung Chiu
National Taiwan Normal University, Taiwan, China

Prof. Lingbiao Gao
South China Normal University, China

Prof. Xingkai Luo
Guangxi Normal University, China

Prof. Zuhao Wang
East China Normal University, China

Prof. Lei Wang
Beijing Normal University, China

Prof. Bing Liu
Tsinghua University, China

Prof. Weiping Hu
Shaanxi Normal University, China

Prof. Xinning Peng
East China Normal University, China

Prof. Junming Wu
Shanghai Normal University, China

Prof. Boqin Liao
Southwest University, China

Prof. Changchun Lin
Chongqing Normal University, China

Prof. Yi Bai
Southeast University, China

Mr. Jianzhong Zhou
Southeast University, China

Prof. Hua Xiang
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, China

Dr. Bing Wei
University of Macau, China

Ms. Yin Zhang
Guangxi Normal University, China

Local Organizing Committee

English Proceeding Editing Committee

Preface

The Development and Changes of Science Education in a Global Age: An Overview of the International Conference on Science Education 2012 (Nanjing, China)

At the age of globalization, different countries have paid more attention to learn from each other to develop human talents in science and technology as well as improve citizen's scientific literacy. Because of differences in culture and tradition between the western and eastern worlds, there have been many challenges when implementing the heavily western-influenced science education theories and practices in China and other Asian countries with Confucian culture tradition. This also leads to reflection of western science education tradition. We hope ICSE2012 (Nanjing) can be a good platform for international science education scholars to share their ideas, experiences, and strategies to address science education challenges; further, we hope through academic exchange we can foster the development of new ideas with eastern cultural flavor to contribute a unique perspective to the advancement of international science education research to inform both theories and practices.

Science education research is vital in the development of national science education policies, including science education standards, teacher professional 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. Because of differences in culture and tradition between the western and eastern worlds, there have been many challenges when implementing the heavily western-influenced science education theories and practices in China and other Asian countries with Confucian cultural heritage. This also leads to reflection of western science education tradition in regard to its cultural values in China and

Confucian cultural circle. China has to support more than 1.3 billion people from 56 ethnic groups with its very limited resources per person; therefore, Chinese science educators might be able to provide different problem-solving approaches when facing common challenges such as global warming and pollution.

To address gaps between understandings of science education in the west and east, the International Conference on Science Education 2012 (ICSE2012) was held Oct. 12–15 in Nanjing University, Nanjing, China (http://edu.nju.edu.cn/zbh/icse2012). ICSE2012 was co-organized by the National Association for Science Education, a branch of the Chinese Society of Education (CNASE) and the Institute of Education of Nanjing University. ICSE2012 welcomed science education researchers from around the world to exchange experiences, challenges, and strategies in science education research around the above-stated areas. These were around a common theme of "Science Education: Policies and Social Responsibilities" with presentations on a range of topics including International Science Education Standards, Public Science Education, and Science Teacher Education.

The conference began with 12 invited plenary presentations—6 invited talks from overseas and 6 invited talks from China—followed by 55 concurrent presentations and 14 posters, including 4 online participants. Representatives from 15 countries came together to share their research and experience on the development and changes of science education in a global age. Major points rose during the sessions included:

- STEM education has dominated some countries' science education policy and is becoming a hot research topic.
- Some countries are developing their new national science education standards with research-based evidence and revolutionary structure and content.
- Science teacher educators should learn from each other.
- Public science education research needs to be more systematic and reliable to guide public science education practice.
- Brain research might provide new approaches for assessment, and scholars have analyzed the issues and solutions to promote science education reform in China.

We hope ICSE2012 (Nanjing) proceedings can provide a good platform for international science education scholars to share their ideas, experiences, and strategies to address science education challenges. Further, we hope that through academic exchange we can foster the development of new ideas with eastern cultural flavor to contribute a unique perspective to the advancement of international science education research to inform both theory and practice.

The conference organizing committee was composed of well-known science education researchers from 22 countries over the five continents around the world. The conference accepted 45 Chinese papers and 33 English papers. There were 122 representatives from 15 countries who attended the conference. They came from China mainland, Chinese Taipei, Macau (China), the USA, the UK, Australia, Russia, Germany, Japan, Singapore, Malaysia, Korea, Iran, Pakistan, and Nigeria. There were also more than 50 graduate student volunteers attending the conference.

The Purposes and Values of the Conference

This was the first big international conference of the National Association for Science Education, a branch of the Chinese Society of Education, since it was founded in 1999. In the context of globalization, science and technology is becoming the center of the world's economy and social cultural development. Understanding the goals, content, methods, and related policies and resources of science education has profound influence on a country's development and world's future. Therefore, the conference aimed to strengthen the academic exchange between Chinese education scholars and their counterparts around the world and understand more about research and development of science education standards, science teacher education, public science education, and related issues. In doing so, we should be able to share experiences and explore the difficulties and challenges we are all facing.

This conference provided an opportunity for the internationalization of Chinese science education; Chinese science education researchers participated in a dialogue with international scholars, strengthened the connection and collaboration of Chinese science education researchers with international science education societies and journals, and contributed to the quality improvement of science education. Meanwhile, we hoped the conference raised awareness of the importance of science education of administrators, scholars, science educators, and related parties to science education. It is hoped that the collective efforts of science education researchers can improve citizen's scientific literacy and develop creativity of science and technology talents.

Carl Sagan maintained that if we arranged things so that almost no one understood science and technology, it would be a prescription for disaster. We might get away with it for a while, but sooner or later this combustible mixture of ignorance and power would blow up in our faces. China is in great need of improvement of its citizens' scientific literacy. It is hoped that science education can help citizens to distinguish science from superstition, facts from opinions, and daily life experience from scientific knowledge. A citizen needs to have enough knowledge and competence to understand and control the direction of science and technology development so that they can improve human life instead of bringing harm. Science education should develop student attitudes in being creative, brave for exploring, and independent; appreciate democracy and laws; and feel happy in pursuing truths. Because of the differences between eastern and western culture, the science and technology based on western culture has encountered challenges in China and Confucian culture dominant countries. Such challenges promote reflection of western science and technology; therefore, we expect new ideas in science education with eastern culture influence so that Chinese and eastern science education researchers can contribute their unique part to the development of international science education.

An Overview of the Conference

ICSE2012 invited 12 presentations, 6 from overseas and 6 from China. We will give a brief description to them and highlight some other presentations aligned with the assertions emerged in the following parts.

The conference was two and a half days. Day 1 included the opening ceremony and 9 invited presentations, all with simultaneous translation. In day 2 there were three invited talks, 55 concurrent presentations, and 14 posters. In addition, four scholars from different countries participated the conference through online conference systems. In order to provide more opportunities for in-depth exchange of ideas, in day 3, there were one workshop and three panels around the three main conference themes, respectively. During the workshop, the cochair of ICSE2012, Prof. Xiufeng Liu, introduced things to consider when publishing an English paper and described the procedures and deadlines of ICSE2012 English and Chinese proceedings.

The Main Topics and Content of ICSE2012

STEM Education Became Dominant Science Education Policies and Became Hot Research Topics in Some Countries

Below we provide a brief description of the invited presentations:

President of ICASE (International Council of Associations for Science Education), Dr. Ben Akpan, reported challenges and issues in Nigeria and some African countries in regard to science education. He expressed his concerns on issues like global warming, population expansion, water shortage, sea pollution, food shortage, and desertification of land. In Nigeria, science education is considered as not only a curriculum but also a driving force for national development. There has been consensus that science education policies determine a country's safety. This conference, indeed, highlights an important tendency in science education—STEM (science, technology, engineering, and mathematics) education.

Professor Sharon Lynch, president of NARST and professor of George Washington University, also introduced STEM education. She introduced her study with her research team about how to build and evaluate effective STEM learning environment. Professor Lynch recalled the American education history. She used research data to indicate that there were no balanced science education resources, and STEM education increased opportunities for students from low-income families. Students were able to work in groups and find answers to questions that their teacher proposed; they developed logical thinking skills during the science inquiry process. Usually a project took 3 weeks; students worked in groups and collaborated and helped disadvantaged students. Students organized by projects and groups was teaching innovation. Students demonstrated their knowledge in different domains, such as biology and physics. Although there were doubts and suspension on the projects, their results showed that students improved their performance significantly; they also had very high attendance and zero dropout.

Dr. Tanya Doyle from James Cook University, Australia, provided an overview of STEM education there in her presentation, The Call to Innovation: Transformed Notions of the Purpose of STEM Education in Australia. She pointed out that although the government embraced the STEM education policies, there were issues between government policies and student receptions in the time of transition.

Related literature also indicated that some European countries, such as the UK, also had beneficial trials in linking national STEM education policies to school practices. All the above information was enlightening when realizing the goals of STEM education.

There Were Revolutionary Changes in the Basis and Content of Their New Science Education Standards in Some Countries

The USA, Germany, China, Korea, and some other countries are revising their national science education standards. Professor Joseph Krajcik from Michigan State University was invited to introduce the new science education standards in the USA. He was an important member of the development team. He used examples to demonstrate how the standards were developed around core concepts, science practices, and cross-domain concepts; the three threads became a rope and were infused in every details and process of science education. The key point of the standards was to allow students to understand the nature of science and promote deep integration of multiple disciplines. He pointed out that the standards were the results of collaboration of scientists, science educators, science education researchers, and science teachers. On the other hand, the recent progress in research on learning progression provided important basis for decision making in curriculum development.

Mr. Peter Nentwig from Kiel University has co-organized two international conferences on national science education standards in 2007 and 2011. The second conference included the most recent results on learning progression research. He pointed out in the invited talk that traditionally German science education was controlled by inputs. The results of PISA 2001 indicated that German students lagged behind in international comparative studies, and this led to the change of German science education from input oriented to output oriented. In 2001, the German Ministry of Education announced a report called Klieme Framework. The framework defined the education goals, competence model, and evaluation system in

Germany. In 2003, Germany announced its national math, German, and first second language achievement standards; in 2004, biology, chemistry, and physics standards were announced. Such standards defined expected student achievements by the end of junior high school. Mr. Nentwig mentioned the concept of competence, that is, the degree of transfer of cognitive tendency. It had three dimensions, the core of the first dimension was thematic knowledge, the core of the second dimension is epistemology, and the third dimension was competence of communication and judgement. Mr. Nentwig said that there were 16 states in Germany, but the central government did not have control over the states in education implementation. The state had their own control over the curriculum; therefore, German national standards could not solve all issues in science education and especially expect immediate results. He mentioned that good curriculum could not solve every issue and a top-down approach might not be effective in curriculum reform.

In order to have more opportunities for exchange among conference participants, Prof. Sung-Jae Pak and cochair of ICSE2012 local organizing committee Prof. Baohui Zhang from Nanjing University organized a panel on science education standards. Professor Sharon Lynch (USA); Prof. Joseph Krajcik (USA); Mr. David Jones (UK); Mr. Peter Nentwig (Germany); Dr. Tanya Doyle (Australia); Mr. Xinqi Lu from Department of Education, Jiangsu Province; and Prof. Weiping Hu (China) joined the panel as invited guests. The panel agreed that for the heavily populated countries, such as the USA and China, there should be national science education standards. The standards are important documents to achieve the goals of science education and ensure equitable distribution of education opportunities and resources. The developers of science education should include science education researchers, scientists, science teachers, education administrators, and related areas; they should each take a specific role in the team and develop the standards collaboratively; members of the development team should respect each other's contribution and settle issues democratically. The panelists also discussed the possibility of establishing an organization and mechanism for constant communication. Professor Zhang and some other panelists suggested that such efforts should be facilitated by existing organizations such as NARST, ICASE, and UNESCO. The conference allowed participants to understand not only some recent moves in science education standards in different countries but also the process for the development of the standards.

Science Education Scholars from Overseas and China Need to Learn from Each Other

Science teacher education can be the "machine tool" of science education. Only when we have good science teacher education, we might be able to have good science teachers and thus ensure the quality of science education. The vice-president of CNASE, Professor Shujin Peng, in his invited talk titled the Development of Chinese

K–12 Science Teacher Professional Development and Science Education Major, introduced the history and current status of Chinese K–12 science teacher professional development. He reflected the formal and informal and mixed development models of science teacher professional development. He proposed policy measures and implementation suggestions to improve science teacher professional development. He expressed the intention for joint efforts in science teacher professional development. Besides his introduction, other participants also shared theories and practices in science teacher professional development, such as those from Chongqing Normal University that emphasized student career development plan and Hebei Normal University. Professor Boqin Liao from Southwest University introduced physics curriculum development reform and challenges in physics teacher professional development. She also pointed out problems raised after test paper design and implementation was assigned to individual province. Xiaowei Tang and Faxian Shao presented a paper titled The Influence of Over-preparing of Demonstration Classes on Primary Science Teachers' Instructional Design and Beliefs—Analysis of the Evolvement of A Science Class. The study indicated that during the preparation of demonstration classes when different understanding of the same goals or mutual emphases on different goals led to conflicts, traditional values and power relationships determined how the trade-offs were made.

Professor Xiufeng Liu from the State University of New York at Buffalo compared the system structure and content of science teacher education systems of the USA and China. He maintained that American science educators might learn how to emphasize the depth of subject knowledge from Chinese counterparts; Chinese science educators, on the other hand, might learn how to teach integrated science (such as physics, chemistry, and biology) (width). Other science education scholars from overseas also demonstrated their related work. For example, Prof. Lilia Halim from Malaysia in her paper titled Students' Perception Concerning Science Teachers' Pedagogical Content Knowledge (PCK) introduced student understanding of teachers' PCK, which helped the development of synergy between teachers and students in teaching and learning. Professor Young-Shin Park from Korea proposed a participatory action research (PAR) model for Korean science teacher professional development.

ICSE2013 international organizing committee cochair, Prof. Shujin Peng, presided over the science teacher professional development panel discussion. Professor Lilia Halim (Malaysia), Dr. Kok Siang Tan (Singapore), Dr. Ben Akpan (Nigeria), and others presented as invited guests. They introduced K–12 science teacher professional development in their own countries, especially their experience in pre- and in-service science teacher professional development. He answered questions about policies, systems, modes of professional development, curriculum setting, ways for teaching practice, and science teacher education research. Scholars from Singapore and Malaysia also made constructive suggestions on how to improve Chinese science teacher professional development. Participants of the panel agreed that scholars from China and overseas should learn from each other while maintaining their own characteristics.

Good Experience from Different Countries in Public Science Education Needs Systematic Summarization and Popularization

Research results showed that Chinese citizen's civic scientific literacy level is only similar to that of some developed countries in the 1980s; therefore, ICSE2013 was also concerned of public science education. Professor Fujun Ren, director of China Research Institute for Science Popularization, presented his talk titled Current Status of Chinese Citizen's Scientific Literacy and Development Tendency of Survey Research. He introduced the results of China's eighth Civic Scientific Literacy Survey. The sample size of this survey was the biggest. All provinces participated in the survey. Professor Ren pointed out that the most important thing of the survey was that the results became the basis of several national policy documents. The institute has collaboration with quite some international institutions including the University of Michigan, European Union, and the like. There are some international publications including those with India.

Although the China Research Institute for Science Popularization tried to have better sampling methods and more reliable results of Chinese citizen's civic scientific literacy survey, the more important thing is to take effective measures to improve Chinese citizen's scientific literacy. Professor Ren and his colleagues from the institute demonstrated many good practices in improving Chinese citizen's scientific literacy. For example, the paper titled Comparative Study of Talent Cultivation for Science Popularization in Higher Education China and Overseas by Hongxia Sun, Fujun Ren, and Rongrong Ren paid attention to the talent cultivation for science popularization. The paper titled Integrating Science and Technology Museum Resources into School Science Learning—Using Astronomy for K-12 Classroom as an Example by Lihui Wang presented how to introduce resources to school science teaching and learning. The paper titled A Survey of Chinese Children's Awareness of Science and Technology based on Problem Collected of 100,000 Super Whys by Keping Sun and Xiaoli Deng detailed how 100,000 Super Whys affected student learning. We were excited that the Chinese government has paid more attention to public science education. On the other hand, the conference committees discovered quite some issues in research design and methods; this indicated much more work is needed in this area.

Scholars from Malaysia, Japan, Pakistan, and Korea also introduced public science education practices in their own countries. They collaborated with scientists and used science museums and centers as bases for public science education. They have also shared their experience in using multiple languages in public science education.

Professor Hongshia Zhang, the cochair of ICSE2012 local organizing committee, presided over the public science education panel. Dr. Takuya Matsuura from Hokkaido University of Education (Japan), Dr. Keping Sun from Shanghai Normal University (China), Dr. Dominador Dizon Mangao from the Center of Science Education Curriculum and Science Population (Philippines), and other participants shared public science education practices in their own countries, respectively. They exchanged ideas about science popularization and research results from their own countries.

Brain Science Research Might Provide New Evidence for Education Evaluation

The evaluation has always been the key and most difficult point in science education. The goals of evaluation have gone beyond student understanding of science and technology. Other models of assessment, such as assessment of learning, assessment for learning, and assessment as learning, also coexist.

Professor Shigeki Kadoya from the Japanese National Institute for Educational Policy Research could not come, so his colleague Dr. Takuya Matsuura presented on behalf of him about how Japan has improved the quality of its science curriculum. Besides emphasizing basic knowledge and skills in science, they have also paid special attention to student thinking skill development through problem solving and science writing in the past 30 years. The report first described the history of curriculum research in the past 30 years (1978–2008). Curriculum research, or Japanese national curriculum research, intended to improve student basic knowledge and skills in science and, more importantly, to improve student competence in thinking, making judgement, expressing self, and problem solving. At the last stage, the emphasis was on using language to improve student thinking skills.

One of the highlights of ICSE2012 was that brain research might provide evidence for education evaluation. Professor Dongchuan Yu from Southeast University gave a talk entitled Issues in Science Education Evaluation. In his talk, he introduced a new electronic biology method, that is, using computer virtual reality environment to demonstrate the process of executive ability training. They discovered student interests by observing their attention to certain phenomena. They maintained that it was the breaking point to select talents with creativity. Professor Yu commented that just like the transition from traditional medicine to modern medicine, schools might be able to build evaluation lab and education reform might be supported by empirical evidence. On the other hand, we noticed that such studies were still basic research; it would be a long way to apply the findings to educational evaluation practices.

Scholars from China and Overseas Were Concerned About the Issues and Way Out

The main purpose of ICSE2012 was to understand the current status and challenges of China's science education reform. Only when we are clear about the problems, it is possible to propose answers to the problems. Professor Zuoshu Wang was from

Capital Normal University, who was also the deputy director of the National People's Congress Science Education Culture and Health Committee and president of the Chinese Association for Non-Government Association. In his invited talk titled Promote Science Education and Education Reform and Improve the Quality of Talent Development, Prof. Wang commented that ICSE2012 might help Chinese science education researchers to connect to the international community and change research paradigm and beliefs. He pointed out that the Chinese science education research started late than its counterparts in many countries, there were only sporadic empirical studies, there had not been a mature system to support science education and research, and there was much space for improvement. He proposed four big questions that also apply to science education although not limited to science education: (1) the goals and content for education, (2) the methods for education, (3). the teachers for education, and (4) the supporting system for education. He hoped science education researchers could find good answers for the four aspects that ensure quality education.

Professor Choyee To had appointment in the University of Michigan and Hong Kong Chinese University, respectively. He was 76 years old by ICSE2012. In his invited talk titled Science Education Popularization and Citizen's Literacy, he analyzed China's current social problems using historical events and proposed suggestions on how to improve China's science education and science popularization. Because he has been traveling in the USA, Hong Kong, and mainland China, his suggestions were quite constructive and insightful.

Professor Hongshia Zhang gave an invited talk titled Values and Limitations of Dewey's Philosophy in the Global Age. She thought that the driving force of human civilization chose western science and technology, empiricism dominated west mainstream education philosophy since ancient Greek time; the core of Dewey's education theory was science and democracy, which took the lead of the twentieth century education theory and practices and continued to have big impact in the twenty-first century. However, when population, resource, and environmental problems became limiting factors for human development, Confucianism, which is good at adjusting human relationship and sharing limited resources and characterized by tolerance and thrifty, had emerged to bare very important education values. Her presentation proposed that China's science education should emphasize science reasoning, observation, and seeking truths; on the other hand, western countries should learn tolerance and self-discipline from Confucianism.

We hope that the abovementioned invited talks and studies in science education standards, science teacher education, science evaluation, public science education and the like have enabled conference participants to have basic understanding of the status and issues of science education in China and some other countries.

Scholars who participated the conference also explored science education theories and practices from other perspectives, such as the paper titled On Science Philosophy and Primary Science Curriculum Reform by Prof. Qiyong Cai, the paper titled Applying Educational Technology to Physics Teaching by Russian scholar Fishman, the Application of Scaffolds in Science Teaching by Singaporean scholars, Using Issue Concept-map to Help Student Understand Science Concepts by Korean scholars, and the like.

Seven public media included China Education Daily, Basic Education Curriculum Magazine, Xinhua Daily, China Social Science Newspaper, Shanghai Social Science Newspaper, Jiangsu Education TV, and China Jiangsu Network along with Nanjing University campus news network, campus TV station, and university newspaper reported the conference. The Chinese conference proceeding will be published by China Science Publishing House, the English conference proceeding will be published by Springer, and selected papers will be published by the *Journal of Science Education and Technology* (SSCI). People who are interested in knowing more about the conference can access the conference web site for updates: http://edu.nju.edu.cn/zbh/.

Science education in the global context intends to integrate science, technology, engineering, and mathematics. Science education policy making should be based on education research. China's science education change needs to learn from the international community, especially science education empirical research paradigm and practices. Meanwhile, Chinese science education scholars should adopt some good international practices according to local natural and social environment and value system. On the other hand, Chinese science educators should also contribute to international science education to play their part. ICSE2012 has provided the latest information about international science education development at the age of globalization. We hope the academic sharing and exchange help improve the quality of science education and science education research.

Nanjing, Jiangsu, China — Baohui Zhang
Buffalo, NY, USA — Xiufeng Liu
Singapore, Singapore — Gavin W. Fulmer
Macau, China — Bing Wei
Xi'an, China — Weiping Hu

Note

This preface is based on the following Chinese paper with modification:

Zhang, B. H., Zhang, H., & Peng, S. (2013). The development and changes of science education in a global age: An overview of the international conference on science education 2012 (In Chinese). *Global Education* (4), 120–128.

Acknowledgment

Finally, the English proceeding of the 2012 International Conference on Science Education (ICSE2012, Nanjing, China) has been finished! We apologize for the delay of publication. We hope to write down the story in the past about 2 years; this is to provide an explanation to readers, conference participants, and all people who care about the conference. Furthermore, the conference and the proceeding have included many people's efforts to make it a success; we hope to write this down as a memo to acknowledge their contribution.

In late November 2011, Hangzhou Normal University hosted the second annual conference of the National Association for Science Education, the Chinese Society of Education (NASE). Professor Baohui Zhang, Institute of Education, Nanjing University, was invited as one of the plenary speakers. He had just returned to work in China after 12 years of studying and working overseas at that time. NASE was new. It was established in 2009 in Nanjing, which includes three subcommittees; the subcommittees represent primary school, middle school, and higher science education practitioner and researcher groups, respectively. In order to raise awareness of science and technology education and improve China's science education and education research in the global age, Prof. Zhang proposed the idea of organizing an International Conference on Science Education. Professor Shujin Peng and Prof. Changchun Lin, who were the leaders of the higher education committee, welcome the idea and brought the proposal to all committee members for approval. After that, the proposal also received agreement from the NASE President, Prof. Yu Wei. The proposal was then supported by Professor Hongshia Zhang, Dean of the Institute of Education at Nanjing University, and Deputy Dean Prof. Yunlai Wang. Professor Baohui Zhang worked with Ms. Mao Cai, Secretary of NASE; the preparation of the conference started in Dec. 2011. Given the fact that an international conference usually takes a year or more to prepare, the conference time was eventually decided to be in mid-October 2012 (it was after China's National Day holiday).

NASE and Nanjing University cohosted the 2012 International Conference on Science Education; the conference venue was in Gulou Campus, Nanjing University. We thank Ms. Cong Cong and Mr. Lijie Pu of the Department of International

Cooperation and Exchange, Nanjing University; Prof. Hongshia Zhang and Prof. Yunlai Wang of the Institute of Education, Nanjing University; and Shandong Yuanda Net & Multimedia Ltd. for their financial support. The fund was used for the hotel, food, and transportation of the invited speakers and simultaneous translation for day 1, and a small budget was allotted for volunteers who provided service for the conference.

The conference attracted 122 registered participants from fifteen countries and regions over the five continents across the world. For the 2½ day conference, we barely made ends meet while we insisted to collect small conference fees. NASE was not allowed to collect membership fees; therefore, the conference committee had very limited budget to run the conference. We thank all of our invited speakers for their support to the conference. They are Prof. Sharon Lynch, Prof. Joseph Krajcik, Prof. Shigeki Kadoya, Prof. Xiufeng Liu, Mr. Peter Nentwig, Dr. Ben Akpan, Prof. Cho-Yee To, Prof. Shujin Peng, Prof. Zuoshu Wang, Prof. Fujun Ren, Prof. Dongchuan Yu, and Prof. Hongshia Zhang. We also thank the Academic Affairs Office for providing their conference venue free of charge for day 2 and day 3. We also thank NARST for providing international airfare for Prof. Sharon Lynch and our co-organizers, the Research Institute for Chemistry Education of Beijing Normal University and the Center for Teacher Professional Development of Shaanxi Normal University, for providing international travel expenses for Prof. Joseph Krajcik and Mr. Peter Nentwig, respectively. Professor Xiufeng Liu and some other invited speakers also shared some costs. It was only through all kinds of financial support that made the conference a success.

The conference preparation and organization followed the international norms. We first set up the international and local organizing committees; we made a call for papers worldwide. The submitted abstracts and papers undergone rigorous reviews; we also provided comments and feedback to authors. For detailed schedule and deadlines, please refer to the conference website: http://edu.nju.edu.cn/zbh/icse2012. The core members of the local organizing committee only included Prof. Baohui Zhang, Dr. Yonggui Liu, Qiaoqiao Cao (doctoral student), Jinlei Zhang (master's student), Leming Liang (master's student), and Ying Wang (master's student). Professor Hongshia Zhang and Prof. Yunlai Wang, the Dean and Vice-Dean of the Institute of Education; Dr. Xiaohua Zong; Ms. Peng Xu; Ms. Jing Wang; and more than 50 volunteers from the institute provided support during the conference. We also thank colleagues from the institute for their care and support to their students who volunteered.

This conference attracted 122 representatives from fifteen countries and regions of the five continents around the world. We thank the authors for their collaboration, understanding, and patience and our international committee members for evaluating the papers and providing their comments and feedback. More responsibilities were taken by the editorial board, which included Prof. Baohui Zhang, Prof. Xiufeng Liu, Dr. Gavin W. Fulmer, Prof. Bing Wei, and Prof. Weiping Hu. Dr. Yin Tao was involved in some related work at one time; we also thank her for her contribution. The person who has helped us the most is Ms. Qiaoqiao Cao (doctoral student in Higher Education and Educational Technology at Nanjing University); she has been the contact person and put everything we read here together. Altogether, there were three rounds of comments and feedback to the submitted abstracts and papers. We have also provided revision to paper format and the like.

Our sincere appreciation also goes to the publisher of the English proceeding, Springer. We thank editors Dr. Leana Li, Dr. Bernadette Ohmer, and Mrs. Ramkumar Rathika for their hard work to speed up the publishing process.

Because of time, manpower, and other constraints, we may not have taken care of all errors in the papers. We hope our future international science education conferences can do a better job on attracting high-level papers and participants.

Nanjing, Jiangsu, China	Baohui Zhang
Buffalo, NY, USA	Xiufeng Liu
Singapore, Singapore	Gavin W. Fulmer
Macau, China	Bing Wei
Xi’an, China	Weiping Hu

Contents

Part I
National/Local Science Education Standards

Chapter 1
History and Challenges of Integrated Science Curriculum Implementation in Zhejiang Province, China

Xiao Huang

Abstract The integrated science curriculum of Zhejiang Province, China, has lasted for nearly 20 years, which started 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, we review the history of science curriculum from "the natural science" to "science" curriculum to know the development process in detail. We also examined teachers' integrated science implementation and the understanding of the nature of science. Data came from classroom observation, surveys, and interviews of teachers and students. Thus, several conclusions are drawn: (1) integrated science and combined science both existed in science teaching practice. (2) Most science teachers paid more attention to the specific dimensions of knowledge and show a lack of concern regarding students' understanding of the nature of science, which is necessary in the current evaluation system. (3) As to scientific inquiry and cooperation, further study was needed, not only into the effectiveness of inquiry and cooperative necessary, but into the operational evaluation of scientific inquiry as well. (4) The role of information technology was often limited to presentations, lacking resource functions, and interactive features. As for the Digital Information Systems (DIS), most science teachers remained unfamiliar with these technologies in science teaching.

Keywords Science • Integrated science curriculum • Curriculum implementation • Scientific literacy • The nature of science

X. Huang (✉)
Education College, Zhejiang Normal University, Zhejiang, China
e-mail: huangxiao@zjnu.cn

B. Zhang et al. (eds.), *International Conference on Science Education 2012 Proceedings: Science Education: Policies and Social Responsibilities*,
DOI 10.1007/978-3-642-54365-4_1, © Springer-Verlag Berlin Heidelberg 2014

1.1 Introduction

The road for integrated science curriculum development has not been smooth (Yu 2008). From 1980s, the integrated science curriculum reform in China started from high school attached to Northeast Normal University, and then some schools in Shanghai carried on science course experiment. Both of them subsequently aborted the integrated science programs. At the end of the 1980s, Zhejiang started the integrated science curriculum reform, which continued to the present. With the eighth national curriculum reform of 2001, integrated science curriculum has already formally become important constitute part of national education course system. Science curriculum standards of compulsory education, which are the bases of science curriculum implementation, were complied. At the beginning, there are only 7 regions against 38 national experimental areas chose the integrated curriculum. Only two million students have used the science curriculum consistently until 2006, after which several experimental withdrew from its implementation. Especially with the withdrawal of the entire city of Wuhan and most parts of Shenzhen, Zhejiang becomes the only place province-wide implemented the integrated science curriculum. Why the integrated science curriculum of Zhejiang became sustainable? What are the main factors that affect the science curriculum implementation? Brief review of history, parsing science curriculum implementation status and challenges, not only contribute to the healthy development of science curriculum in Zhejiang Province but also sheds light on how to adapt implementation of the program to other areas and make nationwide implementation possible.

1.2 Research Design: Content and Method

1.2.1 Research Questions

To provide experience and ways of integrated science curriculum implementation, our main research goal was to show the status quo and challenges of integrated science in Zhejiang. To achieve this goal, we decomposed our issue into a series of questions:

- How did the integrated science curriculum of Zhejiang Province develop? Is it similar to the process experienced in other provinces (such as Wuhan)?
- How was the integrated science curriculum carried out currently in Zhejiang? Is there any worthy of success and experience for other provinces to follow?

What are the issues encountered during the implementation of the integrated science curriculum? What are the effects of these issues on the implementation?

1.2.2 Instruments

In this study, we use questionnaires of “the status quo of integrated science curriculum implementation” and “understanding of the nature of science,” which we compiled ourselves. Multidimensional and multilevel interviews are conducted, and several classroom-teaching videos are taken. As to the questionnaires compile, we not only consult the relevant literature regarding the integrated science curriculum implementation and the nature of science locally and abroad but also consider the continental characteristics of science curriculum reform.

The Science Curriculum Standard (Ministry of Education of the People’s Republic of China 2001) proposed the idea of “comprehensive, independent, cooperation, exploration and difference,” which is reflected in the complication of the questionnaire survey. Three progressive dimensions which are awareness, understanding and application, and self-reflection of the interview outline are concerned. Several parts of integrated science curriculum construction are given: they are the nature of subject and its teaching; reform and innovation of pedagogical content, internal mechanism, and characteristics of learning; and instruction design that embodies students’ development, teaching strategies, and effective teaching evaluation. We designed an interview outline following three progressive dimensions: awareness, understanding and application, and self-reflection. More than 30 science teachers mainly from four different cities and areas were interviewed, and several teaching videos (especially from Lucheng of Wenzhou, Shaoxing, and Binjiang of Hangzhou) were taken for classroom observation to further analyze the pros and cons of implementation.

1.2.3 Methods

In this study, we used questionnaires, interviews, and classroom observations, as well as analyzing the extant literature, to understand the status of the integrated science curriculum and its related issues.

1.2.4 Objects

We mainly took science teachers as our investigation objects, combined with text analysis and classroom teaching, to determine the understanding of science teachers of scientific literacy and the nature of science, which is crucial for science curriculum implementation.

As to the sampling of investigation object, we considered the economy and the culture differences among the cities. In addition to stressing the samples from different cities of Zhejiang Province, we lay particular emphasis on a comparison of Yuhuan and Jinhua (national economic counties).

1.3 The Historical Evolution of the Science Curriculum

The origin of integrated science curriculum in our country was based on the criticism of the subdivided curriculum. In other words, the integrated curriculum and the subdivision of courses were regarded as opposing sides, which not only denied the existence of the reasonableness of the subdivision of courses but also destroyed the relationship between integrated science curriculum and the subdivision of courses. The current integrated science curriculum, which started from "national science" in 1989 and was incorporated into the national science curriculum, has mainly been implemented only in Zhejiang Province.

1.3.1 "National Science" Curriculum Reform in Zhejiang

According to Hongjia Wang's book "New Education Crisis of China," (Wang 2011) the research and development of integrated science curriculum that have been carried out in Zhejiang is based on two facts and are as follows: ① investigation and analysis of the development of international science curriculum. ② Reflection of the problems from the subdivision of courses (physics, chemistry, and biology), such as whether the scientific content is too difficult for compulsory education students to learn, possibly resulting in a high rate of dropouts, and whether students can be cultivated to meet the requirement of social, technological, and economic development.

1.3.1.1 Process of "Natural Science" Curriculum Reform

On November 29, 1989, the chief editor, subeditors, and other members for science textbook development were chosen. Ziqiang Yu acted as the chief editor.

In September 1991, three experiment areas, namely, Guancheng in Cixi, Keqiao in Shaoxing, and Zhuji, carried out the integrated science curriculum reform recognized by the leaders of state educational committee. Five thousand grade 1 junior school students were involved in the experiment.

In February 1992, the experiment was expanded to 24 counties (including Xiaoshan, Longyou, and Qingyuan). Approximately 40,000 grade 1 junior school students were involved in the experiment. "The instructional plan of compulsory education," which reduced the required subjects in junior high school from 14 to 12, decreasing the total hours from 3,066 to 2,648, was built. Approximately 388 elective subjects, activities, and social practices were added.

When implementation of "natural science" (natural science is the predecessor of the integrated science curriculum of Zhejiang, trying to integrate the content of physics, chemistry, biology, and geography) was attempted in the whole province, it suffered opposition from secondary school teachers, principals, university teachers, and academicians. These parties submitted proposals to National People's Congress

(NPC) and Committee of the Chinese People's Political Consultative Conference (CPPCC) through letters and petitions, which show great pressure for the implementation of integrated science curriculum. According to Zhongjie Shao, the editor of Education Commission, "… I can own nothing, but the reform of integrated curriculum cannot give up." The integrated curriculum thus was persisted in.

The experiment was expanded to the whole province in 1993. Whether the science teachers adapt to the comprehensive "natural science" textbook was considered. In 1994, the comprehensive degree of textbook was reduced because science teachers lack the ability to design and implement course from the integrated perspective.

In 1995, academicians and educators put forward their different views about the integrated science curriculum. Fortunately, the integrated science curriculum was supported by Zhichun Xu, the vice governor of Zhejiang Province. Bing Liu correctly set the direction of integrated science curriculum, which enabled the integrated curriculum in Zhejiang to survive.

In February 1998, the seminar on "Integrated Curriculum of Basic Education" was jointly held in Hangzhou by former Basic Education Department of State Education Commission and Zhejiang Province Education Commission. Experts from eight universities and educational institutions (such as People's Education Press, North China Normal University) attended and expressed high regard for the integrated science curriculum reform. The important reform achievement was also reported by CCTV News Broadcasting.

1.3.1.2 Implementation of "Natural Science" Curriculum

The integrated science curriculum in the junior high school of Zhejiang Province is also based on certain social background, science and technology development, and students' learning (Fang 2000). The content selection of "natural science" considers three aspects: improving peoples' science literacy via the integrated STS curriculum, scientific methods training, and patriotism. Thus, the content of science curriculum includes biology (approximately 30 %), physics (approximately 25 %), chemistry (approximately 20 %), geography (approximately 10 %), and integrated topics (approximately 10 %).

As to the features of science materials, two facts were imposed. One characteristic embodied in "natural science" content is focused on inquiry learning, which is undertaken through three steps: ① design a number of exploratory experiments and practice, such as campus observation and practice in Volume I, observation and collection of protozoa and algae in Volume II, installation of a door bell in Volume III, and investigation of the population growth and environmental conditions in Volume VI; ② provide an open forum for discussion, such as the topics of "biotic and abiotic" and "the evolution of nervous system"; and ③ design a variety of scientific exploration activities for one topic, such as design four scientific inquiry activities (Is there starch in soil? Leaves without ultraviolet ray? Green leaves with light? What condition does photosynthesis produce?) for photosynthesis in Volume II.

Another characteristic is the introduction of STS curriculum, which is specifically related to five aspects (Yu 1996): ① the relationship between science and technology, covering technologies and technical achievement when introducing scientific facts, concepts, and principles; ② science, technology, and social issues seminars on population, energy, resources, ecology, and the environment; ③ the personal traits and social responsibilities of scientists, which introduces ten Chinese scientists (Shizheng Li, Xuesheng Qian, Yingxing Song, Longping Yuan, and so on) and six foreign scientists and their achievements and role in economy, culture, and society; ④ the social nature of science, wherein we attempt to summarize science knowledge from historical and social point of view; and ⑤ the characteristics of science, which focus on the scientific method, attitude and spirit, topics of observation, analogy, classification, scientific experiments, mathematical methods, and so on. In addition, "Nature Science" strives to guide students to participate and explore practical issues to understand how science research is conducted.

In the beginning of the reform, two effective measures were adopted to help science teachers to better adapt to the science curriculum. On one side, the content and degree of integration was adjusted, and variety of teaching organization was extended. On the other side, strategies to promote science teacher adaptation were put forward, such as the establishment of teaching and research groups, which require the teachers with different disciplines background to prepare on lesson together. The science teachers aged under 35 were required to teach "natural science" independently. Additional laboratory equipment was needed, as well as full-time laboratory assistants. In addition, science teachers were asked to improve their implementation capacity by attending teaching methods, research, and other various types of training, such as group discussions.

1.3.2 From "Natural Science" to "Science"

A large-scale survey on curriculum implementation of compulsory education was carried out by Basic Education Department of Ministry of Education in 1996 and more than 100 seminars were conducted from 1999 to 2001. "Basic Education Curriculum Reform (Trial)," signaling the new start of basic education curriculum reform, was formally promulgated in 2001. It put forward the combination of the subdivided curriculum and integrated curriculum for junior high school and actively initiated the choosing of the integrated curriculum. And then, "Science (grades 7–9) Curriculum Standards (trial version)" was launched. It proposed four facts of ideas, which are "for all students, based on the students development, embody the nature of science, stress scientific inquiry, and reflect contemporary scientific achievements" to enhance all students' scientific literacy. It marks the science curriculum formally be put on the agenda. According to this document, scientific inquiry and relation of science, technology, and society are most crucial content, as well as physics, life sciences, and aeronautical sciences. Four textbooks were compiled based on the curriculum standards. Thirty-eight experiment areas in 27 provinces (autonomous regions and municipalities) initiated the science curriculum. Nanshan in Shenzhen, Kaifu in Changsha, Lingwu in Ningxia, Quwo in Shanxi, Wuhai in Inner Mongolia, Jinzhou in Dalian, and Gaomi of Shandong were among the first science curriculum experiment areas (later on, Gaomi in Shandong and Jingzhou in Dalian withdrew from the experiment). Zhejiang conducted the experiment in batches: three experiment areas in 2002, the number of 52 in 2003, and the whole province in 2004. "Natural science" curriculum ended its historical mission and was replaced by the "science" curriculum.

With the development of science curriculum implementation, science textbooks based on science curriculum standards were revised. Two kinds of science textbooks were used in Zhejiang; one version was published by the East China Normal University Publishing House, whereas the other version is published by Zhejiang Educational Publishing House, which further developed the "natural science" textbook used by most areas of Zhejiang Province. The "science" textbooks take "the existing nature–the evolution nature–nature and humanity" as clues to comply, shifting from a static to a dynamic nature and focusing on fundamental issues, namely, the relationship between human beings and nature.

As to the problem of science teachers' adaptation to science curriculum implementation, it was gradually solved with the attendance of universities of Zhejiang Province during the new round of science curriculum reform. The major of science education was created by Zhejiang Normal University, Ningbo University, and Shanxing College in 2003. Hangzhou Normal University, Huzhou Normal College, and Taizhou College also established this major in 2004. Also, there are a variety of training programs for the professional development of science teachers.

1.4 Status Quo and Reflection of Science Curriculum in Zhejiang

The integrated science curriculum of Zhejiang, from "natural science" to "science," is nearly two decades old. It is time for us to explore how we can carry the integrated science curriculum reform a step forward. We should face the status of our science curriculum implementation and analyze the problems that confront us. To clarify problems in the practice of integrated science curriculum implementation for two decades, we gathered data regarding the status of integrated science curriculum implementation from more than 500 science teachers in different regions. The research tool covers questions for interview, videos, and questionnaires compiled and revised based on test measurements.

We built indicators in view of the five dimensions understanding of curriculum implementation proposed by Fullan and Pomfret (1977), especially the subject in the curriculum implementation and its relation. It consists of four first-grade indices, which are system of science curriculum (nature of subject, existing curriculum form), science teachers (professional background, science teachers' cultivation and training), science textbook and curriculum (science textbook, science experiment, and other curriculum content), and teaching style and methods (science experiment and other teaching methods). Considering the nature and goals of the science curriculum, we also survey the science teachers' understanding of NOS. As to the questionnaire, we built indicators according to McComas' (McComas and Olson 1998) views of international science education. It covers the nature of scientific knowledge, the nature of scientific inquiry, and the nature of scientific cause. In addition, the interview outline is based on the nature of science curriculum and science curriculum standards, especially on the understanding of "comprehensive, independent, cooperation, inquiry, and difference." We designed it from seven dimensions based on three levels (awareness, understanding and application, self-reflection).

Based on the index construction, we chose science teachers from different districts of Zhejiang Province to survey. We also interviewed them regarding the construction of integrated science curriculum, the nature of science and science curriculum objectives, implementation and reform of science curriculum content, science learning mechanisms and processes, science curriculum implementation strategy and evaluation, the professional development of science teachers, and the environment of science education. We conducted in-depth analysis of integrated science class records (heterogeneous classes, open classes, etc.).

1.4.1 Positioning of Integrated Science Curriculum Form

We can classify comprehensive curriculum by the existence curriculum form and its core. According to the investigation and interview, there are two forms exist in our current science curriculum implementation process. First, "combined science" (physics + geography, biology + chemistry) exists in Riverside District, which is regarded as the kind of intermediate state for integrated science chosen under the existing textbooks system, evaluation system, and teacher professionalism. When we focus on the reasons for "combined science" teaching, some science teachers believe it to be a form adapted to the needs of the current evaluation, which shows knowledge of the subdivided courses in a combined test. Some science teachers believe that "combined science" helps students build an in-depth understanding of scientific knowledge and develop systematic thinking. Of course, "combining science" is partly based on science teachers' professional sources (subdivision development). Second, the "integrated science" form, with integration of physics, chemistry, biology, and geography into one, which is present in Lucheng District, is the ideal form of "natural science."

1.4.2 Objectives and Nature of Science Curriculum

In the survey of science teachers, most science teachers recognized promoting students' understanding of science literacy as the object of science curriculum and teaching; however, they lacked accurate and comprehensive understanding of the content of scientific literacy. Because of the evaluation, teaching materials, and other factors, knowledge and skills are paid much attention in science teaching, whereas "process and approach" and "feelings, attitudes, and values" are often kept outside of science classroom. As to the nature of science, most science teachers focus on "logical," "experimental," and "useful (practical)" in the implementation of science curriculum. Thus, the understanding of science teachers of the nature of science is preliminary and fragmented, and they cannot accurately understand the rich and dynamic content, such as temporary, openness, reproducibility, empirical verifiability, and subjectivity (scientific knowledge based on human imagination and creativity), of scientific knowledge.

Science teachers generally think "science–technology–society" should be emphasized and embodied in science teaching to improve the interest of students in science and their understanding of the significance of learning science. The application of science and technology in the real life is concerned by most science teachers. While they cannot examine science teaching according to STS, they merely add technical and social elements to improve students' interest in learning science, not to help them understand science based on its relation with technology and society.

1.4.3 Development and Utilization of Science Curriculum Resources

The development and utilization of science curriculum resources are relatively lacking. As to the survey, 62.5 % of science teachers believe that their science curriculum resources are very scarce. Specifically, with regard to the science experiments, approximately half of all science teachers reported that their schools have no full-time lab assistant. In addition, 47.1 % and 61.2 %, respectively, of science teachers reported insufficient scientific experiments room and laboratory equipment. Of course, such situations are not only caused by the pressure of science teaching evaluation; science teachers also lack the awareness to develop and utilize the outside curriculum resources, especially the science and technology museum, which requires the convergence of science teaching content and reflection of the important aspects of science, technology, and social relations.

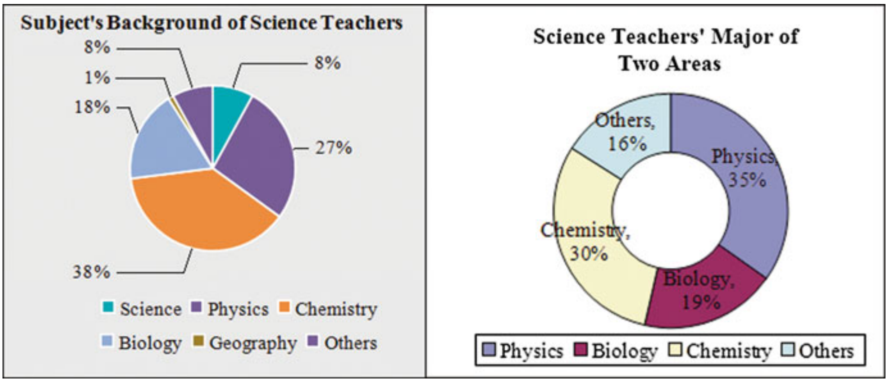
As an important curriculum resource, IT is preferred and often used by most science teachers. While the resources functions and interactive features are not embodies. Specifically, when we utilize DIS for science education, the majorities of science teachers are unfamiliar with the concept and are unable to use DIS for scientific experiments.

Different schools pay different levels of attention to the exploitation of curriculum resources. For example, schools set up areas such as "botanical garden," "herbarium," "geographic park," and "science and technology museum" for students to learn and understand science, whereas schools carry out a variety of practice activities about science, such as competitions about science and technology (e.g., model aircraft competition). However, community and social resources are not fully used. Take Binjiang District as an example, though students are given the chance to visit the

Hi-Tech Park due to its superior geographical environment, they cannot take full advantage of this resource for science learning and put forward problems about the science application and technology. In other words, students fail to establish the relationship between high-tech and science learning, thereby showing the lack of understanding of science and technology links. This phenomenon may be part of the reason STS education implementation should focus more broadly on science and its utilization in society.

1.4.4 Difficulty of the Implementation of Science Curriculum

In the survey, we designed open-ended questions such as “What do you think are the major difficulties encountered in your science teaching?” and “What is the great difficulty facing the science curriculum?” The professional background of science teachers is the main factor for effective science curriculum implementation. According to the survey, the main force of the science teachers comes from physics, chemistry, and biology majors of normal universities. Few possess other professional backgrounds, as shown in the survey of two areas (Yuhuan and Jinhua). Most science teachers feel the lack of relevant knowledge and then spend much time to prepare despite their years of teaching experience. 75.2 % of science teachers feel the lack of nonprofessional-related knowledge in their teaching, 65.1 % of science teachers do not fully grasp the integration of science curriculum, and 45.2 % are not proficient with the experimental skills, except for those covered by their major. Therefore, 72.6 % of science teachers are greatly lacking in nonprofessional knowledge and experimental skills. We further carried out research on the cultivation and training of science teachers, and the results shows that ① the cultivation of science teachers of different colleges shows various disciplines’ stressing, and comprehensive curriculum’s lacking. ② the focus was different for different colleges: mathematics and physics colleges stressed physics, whereas chemical and biochemical colleges focused on the professional basis of biology and chemistry. As for the effectiveness of training, 79.1 % of science teachers think the content, methods, and mechanisms should be improved.



Difficulties in the implementation of scientific experiment not only stem from the demonstration experiment arranged in textbooks but also are due to the lack of laboratory equipment and professional lab assistants. The lack of modern equipment hinders the capacity of science teachers to design experiments, which results in "multimedia experiments" and "blackboard experiments" instead of scientific experiments.

As to teaching method, although 81.3 and 74.3 % of science teachers often adapt inquiry learning and cooperative learning, respectively, the majorities of the science teachers in the interview do not seem to understand inquiry and cooperation and thus experience difficulty in carrying out real inquiry teaching in practice.

The examination and evaluation system of the science curriculum, including the matching degree of difficulty of teaching content and examination question, was also difficult to implement effectively. According to the survey, scientific evaluation standards need to be identified. People's opinions regarding evaluation as "the writer and advocator of science curriculum evaluate the implementation normally according to their experience" and "the opponent of science curriculum generally evaluates the science curriculum implementation according the standard of the subdivision of curriculum" need to be changed.

1.5 Conclusions

The science curriculum of Zhejiang has lasted for two decades, which is a complex interactive process. Some reference can be drawn: ① Zhejiang science curriculum reform is a government-driven type, which got the full support of not only the provincial government but also the board of education. ② Science teachers' cultivation and training are strengthened in science curriculum implementation, and normal colleges of Zhejiang played an important role in science teachers' cultivation and training. ③ The science textbook was constantly revised in line with the development of science curriculum. ④ As to propelling the reform of science curriculum, it is necessary for majority of science teachers to catch and study the question on science teaching practice.

Though the science curriculum keeps steady progress, it presents some problems: ① integrated science and combined science both exist in science teaching practice, which is an intermediate state of the ideal and the reality under the current evaluation system. ② Most science teachers pay more attention to the specific dimensions of knowledge and show a lack of concern regarding scientific method and thinking and students' understanding of the nature of science, which is stressed in science curriculum standard. ③ Science teachers lack of accurate and deep understanding of STS education, the nature of science and scientific inquiry, especially the science teachers couldn't completely understand the meaning of inquiry teaching and cooperative learning, which lead to the lack of effective evaluation of scientific inquiry. ④ Almost all regional schools short of science curriculum resources (such as science laboratories) and most science teachers cannot make good use of the information resources, especially the Digital Information Systems (DIS). ⑤ Though the corresponding mechanisms of science teachers' cultivation and training are built, science teachers' professionalism is still one of the difficulties for science curriculum implementation. ⑥ Science teaching evaluation, which cannot be solved only by education, becomes the bottlenecks of science curriculum reform.

To further deepen Zhejiang science curriculum reform, it is necessary for the government to give full support to enrich the science curriculum resources and to improve the evaluation mechanism. The curriculum plan of science education major of different normal universities (colleges) is required to be modified or reset. We should learn from the implementation experience of international science curriculum and do in-depth research of science curriculum and instruction. Science teachers, as practitioners, should enhance their professionalism by learning theory and reflecting and studying their science teaching.

References

Fang, H. (2000). Integrated science curriculum design of new century. *Curriculum, Teaching Materials and Teaching Methods*, *6*, 31–37.

Fullan, M., & Pomfret, A. (1977). Research on curriculum and instruction implementation. *Review of Educational Research, 47*(3), 335–397.

McComas, W., & Olson,J. (1998). The nature of Science in International Science Education Standard Documents. In McComas, C.(ed.), The Nature of Science in Science Education. Netherlands: Kluwer Academic Publishers

Ministry of Education of the People's Republic of China. (2001). *Science (grades 7–9) curriculum standards of compulsory education (trial version)*. Beijing: Beijing Normal University Publishing House.

Wang, H. (2011). *New education crisis of China*. Beijing: Beijing Publishing House.

Yu, Z. (1996). On the curriculum basis for "natural science" curriculum development. *Interdisciplinary Education, 1*, 23–26.

Yu, Z. (2008). *Science curriculum*. Beijing: Educational Science Publishing House.

Chapter 2
Policies for Broadening Implementation of Research-Based Pedagogy in Undergraduate STEM Education: Possible Models, Limitations, and Solutions

Gavin W. Fulmer

Abstract Research and development on reformed methods of undergraduate science, technology, engineering, and mathematics (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, 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

2.1 Introduction

Undergraduate science, technology, engineering, and mathematics (STEM) education is a major driver of social and economic development, through training of future STEM professionals and development of teachers' knowledge and pedagogy and as a foundation for a scientifically literate citizenry. Research and development on reformed methods of undergraduate STEM instruction have identified various

G.W. Fulmer (✉)
Curriculum, Teaching, and Learning, National Institute of Education, Singapore, Singapore
e-mail: gavin.fulmer@nie.edu.sg

B. Zhang et al. (eds.), *International Conference on Science Education 2012 Proceedings: Science Education: Policies and Social Responsibilities*,
DOI 10.1007/978-3-642-54365-4_2,

pedagogies to support students' learning. Yet despite developments in research-based education, undergraduate STEM instruction still primarily consists of traditional, lecture-based formats (e.g., Borrego et al. 2010), frustrating STEM education researchers and key policymakers.

This evidence of limited implementation signals the lack of consistent, coherent policy models that can support for research-based pedagogies. A step to achieving such coherence is to identify possible models that promote greater levels of implementation of research-based pedagogies in undergraduate STEM education. In this paper I discuss a few such models. The models are chosen to reflect different stances on the relationship among STEM educators, institutions of higher education (IHEs), and policymakers. In the remainder of this section, I present background and definitions for key terms. The following section outlines the proposed models. This is followed by discussion of strengths, limitations, and resolutions for the models. I conclude by discussing directions for policy and research that may further contribute to the evidentiary base on undergraduate STEM education.

For the purposes of this paper, *research-based pedagogy* consists of instructional practices or course organizational structures that are based on findings from education research. Such research may take place within disciplinary STEM departments as well as education departments or schools at various institutions. STEM education research has developed significantly within the various STEM disciplines. Physics saw early work on undergraduates' conceptual mastery of fundamental physical principles (Arons 1969; McDermott 1991; Wieman and Perkins 2005; Docktor and Mestre 2010), which was followed by research in other STEM fields (Towns and Kraft 2010; Lohmann and Froyd 2010; Sierpinska and Kilpatrick 1997). While disciplines have distinct goals for undergraduate education, there exist common features of research-based education, including a focus on conceptual mastery and allowing students to engage in authentic inquiry from early courses (National Research Council 2012). A recent report from the National Research Council provides a broad overview on the subject (National Research Council 2012). While a thorough review of the extensive literature on undergraduate STEM education research would extend well beyond the boundaries of this paper, for example, research-based pedagogies include having students work in groups to explain their ideas to others (Brown and Poor 2010), pose their own research questions to be pursued (Brownell et al. 2012), and engage in argument-driven inquiry (Walker et al. 2012).

By contrast, lecture-based pedagogy—also frequently called traditional pedagogy in undergraduate STEM education—comprises instructional practices that involve an instructor lecturing in front of a large body of students. The instructor may be a faculty member but is also frequently an adjunct professor, lecturer, or even a graduate student. Lectures are often characterized by students as listening to an instructor and taking notes. One of the positive features of lectures that has been frequently cited is that they are time efficient for instructors: a large amount of knowledge can be imparted to students through this format. However, the evidentiary basis to demonstrate that lecture is "effective" for increasing students' conceptual mastery is relatively limited.

Note that there have been studies of adaptations to the lecture format that provide opportunities for student interaction with each other or with the instructor. For example, some prior studies have studied the use of "clickers" to poll students about their thoughts on a topic [e.g., (Lee et al. 2011; Wolter et al. 2011; Morgan and Wakefield 2012)]. If such pedagogies are adopted based on evidence of their instructionally effectiveness, then they are considered research-based (cf. Sevian and Robinson 2011). However, if they are selected because they are time efficient for instructors, then they would still be considered traditional, lecture-based pedagogies.

2.2 Models to Support Adoption of Research-Based Pedagogies

This section describes some possible models for broadening implementation of research-based pedagogies. They are organized into two overall classes: policy-oriented models and facilitation-oriented models. Regardless of which combination of models is adopted, the primary purpose must still be to encourage the use of undergraduate STEM education research findings when making instructional decisions.

2.2.1 Policy-Oriented Models

Policy-oriented models focus on policies at the national, state, or institutional level that will push organizations and faculty members to adopt research-based pedagogies more fully. Overall, such models involve creating policies to push organizations or their entities to implement research-based pedagogies. Three types are identified here.

2.2.1.1 Funding Stipulation Model

Under the funding stipulation model, a funding source can institute a policy that conditions funding on some demonstrated level of research-based pedagogies. The funding sources can include foundations and grant-giving agencies, both private, such as the McDonnell, Lumina, or Spencer Foundation, and public, such as the US National Science Foundation and the National Institutes of Health. This model also applies to state governments' appropriations to fund their respective public universities.

Functionally, implementing this model requires that IHEs measure and certify the extent to which their courses are taught using research-based pedagogies.

IHEs that do not demonstrate some acceptable implementation of research-based pedagogy are reprimanded or penalized. Penalties can include ineligibility to receive grant funding or reductions in funding for departments or programs that do not meet expected standards.

2.2.1.2 Institutional Policy Model

Under the institutional policy model, IHEs can be required to develop or adopt a set of policies that either encourage or mandate some level of research-based instruction. The specific policies that a governing body (state or national government or Boards of Directors or Trustees) or accreditation organizations (e.g., Accreditation Board for Engineering and Technology [ABET]) may require can vary greatly. Some policies may be as minimal as requiring a mission or vision statement that encourages faculty to adopt research-based pedagogies whenever possible. Stricter policy demands may also be imposed. The decision will depend in part on the specific reporting requirements, the metrics available to institutions, and the governing bodies' mandates and stakeholder demands.

This model comprises a variety of policy options available to institutions to support research-based pedagogies. One option, the instructional resource policy, provides funding to facilitate research-based pedagogies through a variety of means, such as implementing smaller classes rather than large-scale lecture courses or reducing teaching loads for tenure-track faculty. A reduced class size or course load may ease the adoption of research-based pedagogies, which often require more direct interaction between instructors and students.

A second option, the course evaluation policy, alters course evaluation systems so that students' responses can be used to measure and reward research-based instruction—rather than measuring very general instructor behaviors as is currently common (cf. Kember and Leung 2011; Marsh 2007).

Finally, the advancement and promotion policy includes research-based pedagogy as a criterion in the promotion, tenure, salary, or merit pay review for faculty members. This policy may also include steps to count publications derived from scholarship on the teaching and learning of STEM subjects—that is, STEM education research—toward promotion and tenure reviews for faculty in education departments and STEM disciplinary departments (cf. Rich et al. 2007).

2.2.1.3 Grant Result Model

Under the grant result model, grant-giving agencies require funded projects to demonstrate how their activities helped to improve, expand, or otherwise increase the quality or incidence of research-based pedagogies. The requirements may focus on the principal investigator's department or institution or extend beyond the institution. This can be used in multiple ways, such as to gauge the success of the project itself, or as a condition for eligibility for future funding.

2.2.2 *Facilitation-Oriented Models*

Reform facilitation models focus on providing financial, technical, or cultural supports that will make the adoption of research-based pedagogies easier and more palatable for institutions and for faculty. Both models may allow leveraging faculty members' professional networks to advance research-based pedagogies (cf. Borrego et al. 2010).

2.2.2.1 Training and Dissemination Model

Under the training and dissemination model, IHEs engage in faculty training and dissemination programs to increase adoption of research-based pedagogies. The funds to support such programs can be provided by local, state, or national foundations—for example, the US National Science Foundation, the Spencer Foundation, or the Carnegie Corporation of New York.

2.2.2.2 Publicity and Recognition Model

Under the publicity and recognition model, IHEs provide outlets to publicly recognize research-based pedagogies within their institution. Faculty members who have demonstrated research-based pedagogy can receive teaching awards or other recognitions for excellence at the department, college, or university level.

2.3 Promise and Problems of the Models

In this section I provide commentary on the potential promise of the selected models. I also address four limitations or potential risks inherent in the proposed models. Some of the limitations and risks are philosophical, in that they relate to the independence of the academy and about faculty members' heuristics for selecting instructional strategies. Other concerns are practical, relating to the technical matters of measuring and evaluating the implementation of research-based pedagogies. I pair each identified limitation with a possible resolution.

2.3.1 *Promise of the Selected Models*

The models presented have varying degree of ease or likelihood of being used. For example, the publicity and recognition model seems among the easiest to implement in the short term: many universities already have awards for teaching excellence. It is only necessary to alter the conditions for recognition to focus on research-based pedagogies.

The grant result model is among the easiest for major funding agencies to implement. For instance, the National Science Foundation could require that all funded projects related to undergraduate STEM education measure and report the degree of research-based pedagogy in the PI's department or university.

The training and dissemination model is already implemented in many instances around the USA. This includes programming to fund training for faculty members, funded through the US National Science Foundation, Department of Education, NASA, or other agencies that invest in STEM education (National Science and Technology Council 2011). For example, the National Science Foundation has offered funding through the Transforming Undergraduate Education in STEM (TUES) program, formerly called Course, Curriculum, and Laboratory Improvement (CCLI). Unfortunately, depending on the specific project, not all funded projects focus on developing or supporting research-based pedagogies (cf. Sevian and Fulmer 2012). Therefore, such funding programs will need to implement a more explicit focus on promoting research-based pedagogies, as well as supporting the scholarship of teaching and learning that is the basis for such pedagogies.

Among the policies contained in the *institutional policy model*, the advancement and promotion policy shows particular promise as a lever for altering the culture among faculty members toward research-based pedagogies. Faculty members' vision of instruction is driven in part by the metrics by which they are measured for advancement. If an institution is able to expand the criteria for advancement to include evidence of research-based pedagogies, then this could rapidly expand the incidence of such instruction (cf. Rich et al. 2007).

2.3.2 Limitations and Solutions of the Selected Models

2.3.2.1 Assumption of Established Knowledge Base

While there is a rich history of STEM education research, particularly at the undergraduate level, the knowledge base for effective instructional practices is relatively new and will continue to grow and change through additional research. Therefore, one of the significant concerns that may be raised is whether there is a sufficient evidentiary basis to prescribe any particular research-based pedagogy. That is, well-meaning colleagues can legitimately ask, "Are we always sure we know what is the right instructional method for this content and for these student?" This concern can be raised regarding any of the identified models.

It is appropriate to be skeptical of claims that any one instructional method will work without a strong evidence base. One of the criticisms of the prevalent, so-called traditional lecture is that its use is assumed to be appropriate and efficient, despite new evidence. Creating a structure in which only one "right" method is embraced may appear promising in the short term but may lead to a lack of innovation and of instructional reform in the long term.

Looking forward, an avenue that could resolve this problem is to embrace the "research-based" aspect of the proposed pedagogies. As new evidence emerges on effective pedagogy, the knowledge base itself will change. Therefore, faculty members and administrators will need to recognize that any "established" pedagogical approaches can and will change with new evidence. This will require a flexible approach to professional development for faculty members, as well as a flexible approach to measuring and rewarding research-based pedagogy. Furthermore, faculty members should be encouraged to think of pedagogy as they think about research: to stay current, one must stay aware of new findings and new methods. This has some similarities to the structure common in the medical community, in which practitioners are expected to stay current on recent findings from medical research when determining appropriate courses of treatment.

2.3.2.2 Institutional Response to Rigidity of Requirements

A second concern that may be raised addresses the level of rigidity of the requirements imposed by a model and how IHEs are to respond to these requirements. This will be particularly true for the funding stipulation and institutional policy models. Faculty and administrators will likely ask for greater flexibility in the implementation of undergraduate STEM education reform.

One basis for this concern is that funding eligibility and institutional requirements for departments, colleges, or institutions may rest upon actions of a relatively small group of faculty (including lecturers, adjunct instructors, and teaching assistants). For example, under the strictest possible requirement—some minimum level of research-based pedagogies among faculty members within each STEM department—failure from any department may risk funding for the entire campus.

If there is little flexibility in the imposed requirements, then there will be greater risks for the institutions. Reform-oriented individuals may feel that this risk is appropriate as a lever to promote adoption of research-based pedagogies. On the other hand, the increased risk may create resentment of the high-stakes requirement, particularly if there is not additional funding provided to help with the transition to a more research-based pedagogy.

An approach to resolve this issue is to create funding stipulations or policy requirements that include some level of flexibility at the institutional level but that emphasize the requirement at the individual or departmental level. In this way, IHEs will not face across-the-board funding cuts. However, as noted, lax requirements may not produce the desired level of adoption of research-based pedagogies. The exact combination of models, and the respective degree of rigidity, will require some experience and further study before the community can determine which combinations yield higher incidence of research-based pedagogy without undue institutional burden.

2.3.2.3 Individual Responses to Rigidity of Requirements

Another concern addresses implications for individual faculty members and their instructional decisions. One source for such concern may be expectations among faculty that they have some degree of autonomy in their teaching. That is, faculty members may be concerned with how narrowly "research-based pedagogies" are defined and measured. These individuals may question how well such strict policies can accommodate their instructional decisions—based on their knowledge of the subject, their students, and their pedagogical expertise.

Essentially, this concern addresses whether and how to encourage research-based pedagogies while also freeing faculty members to decide which specific instructional strategies to use. If policies are implemented very strictly, faculty members may perceive the reform as an unwelcome intrusion in their teaching. While many who support adoption of research-based pedagogies may wish to see some level of intrusion, negativity among faculty members may have the effect of fueling strong push-back against reform.

Furthermore, instructors' decisions are not made entirely in isolation. Particularly for large lecture courses, the content, curriculum, and the instructional materials may all be decided by committee and influenced by departmental or university degree requirements. Depending on the nature of the course and the status of the instructor, she or he may have little input into the materials, the course format, or the suggested instruction.

One possible solution to this concern is to provide opportunities for faculty members to specify how they made an instructional decision to use research-based pedagogies (or not). This may be necessary in addition to measures of whether or how well an instructor implemented research-based pedagogies.

2.3.2.4 Practical Problems with Measurement and Evaluation

There are practical problems that affect the selection and evaluation of the presented models. First, there is a problem with measuring research-based pedagogy at an institutional level. Second, there is a problem with evaluating instruction while accounting for the system of influences that surround instructional decisions. These problems are of concern regardless of the combination of models implemented, but the stakes are particularly high for the funding stipulation and institutional policy models. Many of these issues arose tangentially in previous discussion but can be summarized into two categories: the measurement perspective and the evaluation perspective.

From a measurement perspective, it is necessary to identify the appropriate sample for the population, the appropriate instrument, and the appropriate methodology. Regarding the population and sample, it must be clear which institutional units (e.g., colleges, departments) are of interest. It must also be clear whether all STEM courses are to be considered, only introductory courses, or whether institutions can stagger their implementation and measurement. Additionally, it must be clear which instructors are to be included—only faculty members or also all nontenure-line lecturers, adjunct faculty, graduate teaching assistants, etc. Furthermore, it must be decided whether it is sufficient to collect data from a sample of these individuals or whether it is necessary to conduct a census of all instructors.

Regarding the measurement instrument and methodology, it must be clear how "research-based pedagogies" are going to be defined and what types of data are needed to determine if instructors are engaging in it. For example, it may be sufficient to ask all faculty members to complete a survey about their teaching. However, there are limitations on how accurately an instructor can rate their own practice. Their responses may not reflect their actual performance—because of a general problem with self-report methods (cf. Donaldson and Grant-Vallone 2002) and the potential repercussions for faculty, their department, or the institution. Therefore, it may be necessary to implement some combination of faculty surveys, student surveys, and course observations. If student surveys are to be included, then these surveys must also be adapted to be sensitive to research-based pedagogies and traditional teaching, to enable accurate estimation of differences among the instructors' practices (cf. Fulmer and Liang 2012).

These decisions have real, practical implications for the complexity and cost of measuring the quantity or quality of research-based pedagogies within an institution. If all STEM instructors need to be evaluated, using faculty survey, student surveys, and observations, the costs will be prohibitive. On the other hand, randomly sampling some proportion of courses may be adequate for estimating the prevalence of research-based pedagogy with greater cost efficiency. However, random sampling may not meet expectations for assessing broad implementation under some policy or funder requirements.

There are multiple features needed to achieve a solution to the measurement concern. First, it may be cost-effective and informative to select only a sample of eligible instructors. This will reduce the institutional burden, administrative challenges of data collection, and demands on the entire faculty body. Second, the data collected on instructors' teaching can include a combination of faculty surveys, student evaluation tools, and class observations. This will result in a more robust indicator of the enacted instruction that extends beyond merely self-report measures.

From an implementation perspective, there will always be problems with efforts to increase the frequency and quality of implementation of particular instructional practices—in institutions of higher education just as in primary and secondary schools. Part of the concern is that there are many influences on faculty members' instructional decisions. At the individual level, these can include their experience as a student in undergraduate or graduate study, their perception of what "good teaching" is, and the amount of time available for them to develop and plan their courses, among others. At an organizational level, these can include the institutional resources that support instructional improvement, the institutional and departmental expectations about teaching, and the department's climate and culture regarding research-based pedagogy, among others (cf. Borrego et al. 2010; Baldwin 2009). Fully understanding the various, complex influences (Porter et al. 2006), and identifying appropriate approaches that will encourage adoption of research-based pedagogy, is a daunting task.

There are not necessarily easy solutions to the concern about factors that can support or impede implementation. To understand and respond to the effects of organizational differences will first require efforts to measure how much the various influences (department climate, prior experience) contribute to instructors' willingness, knowledge, and effectiveness to adopt research-based pedagogies. That is, the field requires a rich body of research on faculty members' understanding and response to research on undergraduate STEM teaching and learning. With this information it will be possible to develop faculty outreach programs that can support instructional innovation more sustainably.

2.4 Conclusions and Directions

In this paper I have explored models for supporting implementation of research-based pedagogies in undergraduate STEM education. Each model may be effective to some extent, but no one model may be sufficient. There are also limitations for each of the models. Therefore, reform will likely require a great deal of experimenting to determine what combination of models and solutions is most effective in a given context or across contexts.

The continued success of "research-based pedagogy" depends in large part upon the ongoing development and refinement of such pedagogies. Therefore, successful education reform will require continued financial support for the research on undergraduate STEM teaching and learning. Additionally, continued support will be necessary to increase faculty members' knowledge of and willingness to engage in research-based pedagogies. With the same funding mechanisms, such funding programs should also encourage research on the conditions or characteristics that can facilitate faculty members' understanding and responsiveness to the scholarship of undergraduate STEM education. This will strengthen future projects to increase adoption of research-based pedagogies among faculty members.

Furthermore, before engaging in a large-scale effort to stimulate adoption of research-based pedagogies, it will be essential to understand the current "state of the field" in terms of the frequency and quality of research-based pedagogy in use. Such a survey can provide a broad snapshot of the current situation and serve as a baseline to which future studies could be compared.

Acknowledgments The author wishes to thank Hannah Sevian (University of Massachusetts–Boston), Baohui Zhang (Nanjing University), and anonymous reviewers for their comments on an earlier draft of this paper.

References

Arons, A. B. (1969). Science: The art of inquiry. *Change in Higher Education, 1*(3), 31–35.

Baldwin, R. G. (2009). Climate change: Creating conditions conducive to quality STEM undergraduate education. *New Directions for Teaching & Learning, 2009*(117), 97–101.

Borrego, M., Froyd, J. E., & Hall, T. S. (2010). Diffusion of engineering education innovations: A survey of awareness and adoption rates in U.S. engineering departments. *Journal of Engineering Education, 99*(3), 185–207.

Brown, S., & Poor, C. (2010). In-class peer tutoring: A model for engineering instruction. *International Journal of Engineering Education, 26*(5), 1111–1119.

Brownell, S. E., Kloser, M. J., Fukami, T., & Shavelson, R. (2012). Undergraduate biology lab courses: Comparing the impact of traditionally based "cookbook" and authentic research-based courses on student lab experiences. *Journal of College Science Teaching, 41*(4), 36–45.

Docktor, J., & Mestre, J. (2010). *A synthesis of discipline-based education research in physics*. Washington, DC: National Research Council.

Donaldson, S. I., & Grant-Vallone, E. J. (2002). Understanding self-report bias in organizational behavior research. *Journal of Business and Psychology, 17*(2), 245–260. doi:10.1023/a:1019637632584.

Fulmer, G. W., & Liang, L. L. (2012). Measuring model-based high school science instruction: Development and application of a student survey. *Journal of Science Education and Technology, 21*(1), 114–124. doi:10.1007/s10956-011-9287-2.

Kember, D., & Leung, D. (2011). Disciplinary differences in student ratings of teaching quality. *Research in Higher Education, 52*(3), 278–299. doi:10.1007/s11162-010-9194-z.

Lee, A., Ding, L., Reay, N. W., & Bao, L. (2011). Single-concept clicker question sequences. *Physics Teacher, 49*(6), 385–389. doi:10.1119/1.3628273.

Lohmann, J., & Froyd, J. (2010). *Chronological and ontological development of engineering education as a field of scientific inquiry*. Washington, DC: National Research Council.

Marsh, H. W. (2007). Do university teachers become more effective with experience? A multilevel growth model of students' evaluations of teaching over 13 years. *Journal of Educational Psychology, 99*(4), 775–790.

McDermott, L. C. (1991). Millikan lecture 1990: What we teach and what is learned—Closing the gap. *American Journal of Physics, 59*(4), 301–315.

Morgan, J. T., & Wakefield, C. (2012). Who benefits from peer conversation? Examining correlations of clicker question correctness and course performance. *Journal of College Science Teaching, 41*(5), 51–56.

National Research Council. (2012). *Discipline-based education research: Understanding and improving learning in undergraduate science and engineering* (Committee on the Status, Contributions, Future Directions of Discipline-Based Education Research, Board on Science Education, Division of Behavioral Social Sciences Education). Washington, DC: The National Academies Press.

National Science and Technology Council. (2011). *The Federal Science, Technology, Engineering, and Mathematics (STEM) education portfolio: A report from the federal inventory of STEM education fast-track action committee* (Committee on STEM Education). Washington, DC: Author.

Porter, A. L., Roessner, J. D., Oliver, S., & David, J. (2006). A systems model of innovation processes in university STEM education. *Journal of Engineering Education, 95*(1), 13–24.

Rich, F., Chance, C., & Battles, D. (2007). Effecting institutional change in faculty roles, rewards and recognition: A case from Georgia Southern University. *Widening Participation and Lifelong Learning, 9*(3), 47–50.

Sevian, H., & Fulmer, G. W. (2012). Student outcomes from innovations in undergraduate chemistry laboratory learning: A review of projects funded by the U.S. National Science Foundation between 2000–2008. *Educación Química, 23*, 149–161.

Sevian, H., & Robinson, W. E. (2011). Clickers promote learning in all kinds of classes: Small and large, graduate and undergraduate, lecture and lab. *Journal of College Science Teaching, 40*(3), 14–18.

Sierpinska, A., & Kilpatrick, J. (Eds.). (1997). *Mathematics education as a research domain: A search for an identity*. Dordrecht: Kluwer.

Towns, M., & Kraft, A. (2010). *Review and synthesis of research in chemical education from 2000–2010*. Washington, DC: National Research Council.

Walker, J. P., Sampson, V., Grooms, J., Anderson, B., & Zimmerman, C. O. (2012). Argument-driven inquiry in undergraduate chemistry labs: The impact on students' conceptual understanding, argument skills, and attitudes toward science. *Journal of College Science Teaching, 41*(4), 74–81.

Wieman, C., & Perkins, K. (2005). Transforming physics education. *Physics Today, 58*(11), 36–41.

Wolter, B. H. K., Lundeberg, M. A., Kang, H., & Herreid, C. F. (2011). Students' perceptions of using personal response systems ("clickers") with cases in science. *Journal of College Science Teaching, 40*(4), 14–19.

Chapter 3
Commonalities and Trends in High School Chemistry Curriculum Standards: By Comparison of International Curriculum Standards

Lei Wang, Mingchun Huang, Weizhen Wang, Yanxia Jiang, Lina Zhang, and Ronghui Zhang

Abstract In order to make decisions on revising Mainland China's national chemistry curriculum standards, pairwise comparison has been conducted on high school chemistry curriculum standards of Mainland China and those from selected countries/regions. By comparing standards in six aspects such as curriculum setting, standards structure, curriculum philosophy, curriculum goals, curriculum content, and curriculum assessment, some similarities and differences in high school chemistry curriculum standards were found. Six exemplary features that reflected the commonalities and trends were extracted. 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, and curriculum evaluation, thematic studies have been done, from which we were informed by curriculum settings, built a preliminary progress map of chemistry core concepts, learned about the breadth and depth of chemistry knowledge in different countries/regions, and discovered some trends of performance standard, the demand of ability, and curriculum evaluation in high school chemistry standards.

Keywords Chemistry curriculum standards • Curriculum structure • Learning progression • Chemistry core concepts • The breadth and depth of knowledge content • Performance standard • The demand of ability • Curriculum evaluation

L. Wang (✉) • M. Huang • W. Wang • Y. Jiang • L. Zhang • R. Zhang
Institute of Chemical Education, Beijing Normal University, Beijing, China
e-mail: wangleibnu@126.com; hmc91810@126.com; vijane@126.com; jyx814@163.com; linacat630@sohu.com; zrh8810@163.com

B. Zhang et al. (eds.), *International Conference on Science Education 2012 Proceedings: Science Education: Policies and Social Responsibilities*,
DOI 10.1007/978-3-642-54365-4_3,

3.1 Introduction

The basic education reform in Mainland China (2001) driven by curriculum standards has brought big changes in chemistry curriculum, instruction, and assessment. Meanwhile, controversy arose mainly in three aspects: curriculum setting, level arrangement, and assessment, for example, the depth of knowledge in compulsory modules 1 and 2, the order of elements and compounds knowledge with the periodic law, the level arrangement of required and selective curriculum, and the difficulty of the structure of matter in selective curriculum (Wang 2010). Revisions to senior high school chemistry curriculum standards are needed according to the Ministry of Education, China.

This research is going into efforts to revise senior high school chemistry curriculum standards by providing an analysis of the science and chemistry standards in different countries/regions whose students perform well on international assessments: OECD (2007) and National Center for Education Statistics, Institute of Education Sciences, U.S. Department of Education (2009) and/or countries of interest.

It is meant to help answer five questions important to addressing the challenges in reality and to inform the amendment of the high school chemistry standards for Mainland China. Our analysis was guided by five questions:

1. What are exemplary features of the standards reviewed in this research which can reflect the commonalities and significant trends in high school chemistry standards?
2. What are the commonalities and trends in senior high school chemistry curriculum setting? How do the results inform scholars in Mainland China?
3. What are the common contents that countries/regions expect students to learn at the primary, lower secondary, and upper secondary school levels in chemistry? What does the learning progression of different concepts look like?
4. How do the breadth and depth of knowledge in senior high school chemistry curriculum content in Mainland China compare to those in other regions?
5. How do the commonalities and trends in senior high school chemistry curriculum assessment in terms of performance expectations, ability, and assessment compare among different countries? How do the results inform us?

3.2 Research Framework and Methods

This study had two steps: The first step is pairwise comparison, which was based on specific countries/regions. We compared the chemistry curriculum standards in six aspects: curriculum setting, curriculum standards structure, curriculum philosophy, curriculum goals, curriculum content, and curriculum evaluation. This step aimed at discovering the characteristics and finding the exemplary features worthy of concern.

In the second step, we had six thematic studies on curriculum setting, learning progressions on chemistry core concepts, the breadth and depth of knowledge, performance standards, the demand of ability, and curriculum evaluation. Those six keywords were extracted from the first step. The second step of the research was a cross-sectional study, while the first step is more like a longitudinal study.

The study selected countries/regions for inclusion based on the criteria that whether a country was a high performer on international assessments, OECD (2007) and National Center for Education Statistics, Institute of Education Sciences, U.S. Department of Education (2009), and/or important to Mainland China for economic, political, or cultural reasons. Nine senior high school chemistry curriculum standards were selected including those from the United States (College Board 2009), Canada (Ontario Ministry of Education 2008a), France (Ministère français de l'Education 2010), Finland (Finnish National Board of Education 2003), Japan (Ministry of Education, Culture, Sports, Science and Technology 1999), Korea (교육인적자원부 2007), Taiwan (Ministry of education 2008), the State of Victoria in Australia (Victorian Curriculum and Assessment Authority 2005), and the United Kingdom (Great Britain Department for Education and Employment 2011). Pairwise comparison and five thematic studies except for learning progressions on chemistry core concepts used those nine documents as analysis objects. The research on learning progressions selected 51 more standards, including documents from Singapore (Singapore Ministry of Education 2008; Singapore Examinations and Assessment Board 2013), the United States (National Research Council 2012), and other regions' standards in the United States (Arizona Department of Education-Standards Based Teaching and Learning 2005; Alaska State Board of Education and Early Development 2006; Board of Education Commonwealth of Virginia 2010; California State Board of Education Sacramento 2004; Colorado Department of Education 2009; Connecticut State Department of Education 2004; Delaware Department of Education 2008; Florida Department of Education 2012; Georgia Department of Education 2006; Hawaii State Department of Education 2005; Idaho State Department of Education 2008; Illinois State Board of Education 1997; Iowa Department of Education 2009; Indiana State Board of Education 2010; Kentucky Department of Education 2002; Kansas State Department of Education 2007; Maryland State Department of Education 2000; Massachusetts Department of Education 2006; Michigan Department of Education 2000, 2010; Mississippi Department of Education 2010; Minnesota Department of Education 2009; New Hampshire Department of Education 2006; New Jersey Department of Education 1998; New Mexico State Department of Education 2003; North Dakota Department of Public Instruction 2002; New York Education Department 2009a, b; North Carolina Department of Public Instruction in Science 2004; Pennsylvania Department of Education 2010; South Carolina Department of Education 2005; Texas Department of Education 2010; Tennessee State Board of Education 2009; Utah State Board of Education 2002, 2003a, b; Vermont Department of Education 2000; Virginia Board of Education Commonwealth 2010; Wisconsin Department of Public Instruction 2000; Wyoming State Board of Education 2008).

The analysis has both quantitative and qualitative components. Qualitative analysis was a major method, which summarized the commonalities and differences through comparison and analysis of the text. The quantitative analysis was mainly reflected in the study of the learning progressions on chemistry core concepts. Practice was as follows: comparison and analysis of 60 countries/regions curriculum standards documents, statistical frequency of a concept in these curriculum standards, and the grade distribution. For example, 32/60 curriculum documents have a statement of a concept at junior high school, and this data would be used as a certification that this concept should be arranged in junior high school curriculum standards.

3.3 Analytical Framework

The study used the following analytical framework (Tables 3.1, 3.2, 3.3, and 3.4):

Table 3.1 Analytical framework of pairwise comparison

I	Curriculum setting
II	Standards structure
III	Curriculum philosophy
IV	Curriculum goals
V	Curriculum content
VI	Curriculum assessment

Item / Region	I		II		III		IV		V		VI	
	S	D	S	D	S	D	S	D	S	D	S	D
A-B												
A-C												
A-D												
A-E												
A-F												
A-G												
A-H												
A-I												
A-J												

S:similarities
D:differences

A, Mainland China; B, United States; C, France; D, Japan; E, Korea; F, Ontario, Canada; G, Finland; H, Victoria, Australia; I, Taiwan; J, United Kingdom. B[1], Framework 2012; B[2], College Board (2009); B3-B^n, states of the United States

Table 3.2 Analysis framework of learning progressions on chemistry core concepts

Core concept

	The core concept expression	Grade
A	……	(K-12)
B1	……	
B（2-47）	……	
C	……	
D	……	
E	……	
F	……	
G	……	
H	……	
I	……	
J	……	

Concept expression summary

Concept grade distributions

Table 3.3 Analysis framework of the breadth and depth of knowledge

	A		B[2]	C		D		E		F		G		H		I		J	
	C	E	E	C	E	C	E	C	E	C	E	C	E	C	E	C	E	C	E
I																			
II																			
III																			
IV																			
V																			
VI																			
VII																			
VIII																			
IX																			
X																			

I, element compounds; II, chemical bonds and molecule structure; III, atomic structure; IV, reaction rate; V, chemical equilibrium; VI, gas; VII, aqueous solution; VIII, electrochemistry; IX, chemistry thermodynamics; X, organic chemistry

Table 3.4 Analytical framework of chemistry curriculum setting and chemistry assessment: the performance expectation, the ability, and the assessment part

	Overview	Feature
B-college board		
C		
D		
E		
F		
G		
H		
I		
J		

stability and trends → enlightenment

3.4 Findings and Conclusions

3.4.1 Features and Trends in Chemistry Curriculum Standards All over the Countries/Regions

In pairwise comparison, the prominent features of the high school chemistry curriculum standards were found in these six aspects. It appears on the Table 3.5 below:

Table 3.5 List of keywords that embodies the characteristics of the high school chemistry curriculum standards of various countries/regions through pairwise comparisons

	I	II	III	IV	V	VI
B		Performance expectation		Ability	O&S	Operational
C	Physical science			Grade; skill		
D	Multi-choice			Ability		Structural
E	Multi-level					
F	Multi-track		NOS	Grade		Structural
G	Multi-path			Ability		
H				Skill		Operational
I				Grade; ability		
J	Multi-stage					

O organization, *S* selection

From the statistical table, we can see that chemical education researchers from various countries/regions did a useful exploration in chemical curriculum setting. All the documents reflect three elements of curriculum selection: students' career orientation, grades, and content level. Those three elements are the foundation of curriculum setting.

About selection and organization of curriculum content, on the one hand, we found that a stable manner of organizational structure in international chemical curriculum content has been formed, which reflected in the sorting out of learning progressions of chemistry core concepts through cross-sectional research on international curriculum standards. But on the other hand, modes of organization and selection chemistry content differed from various countries/regions, and the breadth and depth of some thematic content is not the same. Research on breadth and depth of thematic content has important guiding significance for the selection of specific chemistry content in Mainland China.

In curriculum evaluation, feature of structural and operational is also worthy of our attention. It can help content standards connected with performance standards. We need to think about how to highlight the requirements and describe the students' learning level in the curriculum standards. Various countries/regions were trying to solve this problem by proposing the "capacity requirements" and "performance standards." Therefore, the analysis and summary of these two aspects can also help us to achieve the consistency of the curriculum content standards and microscopic evaluation criteria.

Accordingly, three research areas were determined: the curriculum setting, the curriculum content, and the curriculum evaluation. Then a special research of the six themes were conducted: curriculum setting, learning progressions on chemistry core concepts, the breadth and depth of knowledge content, performance standard, the demand of ability, and curriculum evaluation.

The following is the thematic research conclusions with the enlightenment.

3.4.2 Commonalities and Trends in Senior High School Chemistry Curriculum Setting

Nine senior high school chemistry curriculum standards of academic tendency were selected, and their chemistry curriculum structure was analyzed, from which we noted that the high school chemistry curriculum structure design should pay attention to three aspects.

First is the appearance of chemistry in senior high school. The chemical content generally occurs in three forms: science, physical science, and chemistry. Of all the nine countries/regions, only France uses physical science as a form of chemistry all through senior high school. The rest are in the form of chemistry in selective stage.

Second is the diversity of students' job segregation orientation. Chemistry, as an elective content in senior high school, is for students of different professional orientation. In some countries, some students do not need to learn chemistry, such as Japan and Finland.

Third is the division in senior high school chemistry curriculum. One is horizontal types, and the other is vertical levels. Chemistry in senior high school all over the countries/regions has been divided into compulsory and selective level. Only Ontario in Canada and Taiwan set chemistry into two levels in compulsory phase. Divisions of horizontal types and vertical levels embodied the problem in curriculum organization.

In addition to the above common features, we also found that the students' job segregation has a close connection with chemistry curriculum setting. But few countries/regions are able to handle well the relationship between students' job segregation and chemical content organization of both horizontal and vertical. At this point, Ontario in Canada is a successful case.

We had learned the following things from thematic research on curriculum setting to the revision of chemistry curriculum in Mainland China:

1. In selective stage, we had horizontal category in chemistry but slightly lack of the hierarchical level division. Especially under the impact of the college entrance examination, such content organization manner may lead to the situation that although we have many elective module, the selection mode is still single.
2. Due to the longtime impact of arts and science division in our country, a situation may arise in chemistry curriculum setting wherein even if there are many modules, students still choose a single module. It reminds us that when we meet the issue on job segregation of senior high school students, we should first consider about looking for more professional orientation and then think of the establishment of the convenient track to get through these orientations.
3. In terms of chemistry experiment content, currently, only Mainland China and Taiwan arrange it as an independent elective module. But in practice, this selective module was often subjected to the impact of the other chemical knowledge and

has been overlooked in Mainland China, while in Taiwan, this part of content belongs to the compulsory module. Therefore, when it comes to the experimental part, its module selection is Debatable.

3.4.3 Learning Progressions on Chemistry Core Concepts

In this study, learning progressions on chemistry core concepts refers to the distribution of the different grades span and specific statement of the core concepts in high school chemistry. It points directly to the selection and organization problems of chemistry curriculum content. The reason that we can get this kind of progress map is based on the premise that, so far, the international selection and organization of chemistry curriculum content has been basically stable at the macro level and has reached a consensus.

We selected a total of 72 curriculum standards documents including A Framework for K-12 Science Education: Practices, Crosscutting Concepts, and Core Ideas; the states' science and chemistry curriculum standards in the United States; and 9 curriculum standards mentioned above. By analyzing these documents, we collected statistical frequency of the concepts contained in these curriculum standards and their grade distributions. After this statistical analysis, we can conclude the learning progressions of various core concepts.

Take periodic table and periodic law as an example. First of all, all the statements which are connected with it have been collected. Then we integrated the expression of specific statements and used excel spreadsheet statistics, the statement frequency of it in those curriculum standards, and their grade distributions (Table 3.6).

Finally, the learning progressions of periodic table and periodic law will be constructed.

For example, a complete statement of periodic table and periodic law that we found in junior high school is as follows:

In junior high school, the periodic table is a tool/model, for element classification, to determine the nature of the elements.

① *The periodic table is a tool for organizing elements.*
② *The symbol of element in the periodic table is a representative of the various elements of the composition of matter; from the corresponding position in the periodic table, we can identify the elements in the chemical formula of the simple compound.*
③ *The periodic table presents the atomic number and atomic weight of the element.*
④ *The periodic table elements are organized in accordance with the increase in atomic number (number of protons). The atomic number is incremented from left to right and from top to bottom in periodic table.*
⑤ *Column elements in the periodic table of elements have similar chemical properties.*
⑥ *The elements of the periodic table were classified as metals, nonmetallic, inert gas, etc. By category we can predict the chemical property of the substance.*
⑦ *The periodic table was originally constructed according to the atomic weight.*

Table 3.6 Grade distributions of periodic law

“Periodic table and periodic law”												
	Periodic table is a tool/model: for element classification, to determine the nature of the elements											
	1	2	3	4	5	6	7	8	9	10	11	12
B1						1	1	1				
G							1	1	1			
E								1				
J							1	1	1			
SI							1	1	1			
B2						1	1	1				
B3						1	1	1				
B4								1				
B5						1	1					
B6							1					
B7						1						
B8						1	1	1				
B9						1	1	1				
B10						1	1	1				
B11								1				
B12								1				
B13							1					
B14							1	1	1			
Frequency						8	12	14	3			
Conclusion	*The contents are mainly distributed in the junior high school – Grade 8*											

B3, New York Intermediate Level Science (2009a, b); B4, California (2004); B5, Kansas (2007); B6, Minnesota (2009); B7, New Hampshire (2006); B8, New Jersey (1998); B9, Maryland (2000); B10, North Dakota (2002); B11, New Mexico (2003); B12, North Carolina (2004); B13, South Carolina (2005); B14, Virginia (2010)

⑧ *The periodic table reveals the internal relations of atomic structure. We can use it to determine the number of protons and number of neutrons and number of electrons.*

Through frequency statistics of the core concepts in different grades span and concept expression integration, we found that the design of chemistry core knowledge content has basically formed a stable mode, which reflected as a relatively clear hierarchy model, so that we can get the overall chemistry core concepts learning progressions.

3.4.4 The Breadth and Depth of Chemistry Knowledge in High School

This thematic research is about the results of knowledge selection and organization, which belongs to the area of curriculum content selection and organization. This part of our analysis will focus on two aspects: (a) comparing the knowledge

Table 3.7 The results of the comparison of breadth and depth of knowledge

	A	A	B1	F	F	I	I	D	D	E	E	G	G	C	C	H	H
	C	E	E	C	E	C	E	C	E	C	E	C	E	C	E	C	E
Element compounds (inorganic)	1	0	1	0	0	0	2	1	0	1	1	0	1	0	0	0	0
Chemical bonds & molecule structure	1	2	2	3	4	1	4	0	1	0	1	3	1	0	4	3	0
Atomic structure	1	2	4	3	4	1	4	1	1	0	2	0	1	1	0	1	0
Reaction rata	1	2	4	0	4	0	4	0	1	0	1	0	1	0	2	0	1
Chemical equilibrium	0	2	1	0	4	0	1	0	1	3	1	0	1	0	2	0	1
Gas	0	0	4	0	1	0	4	0	0	0	4	0	0	1	0	1	0
Solution	1	2	1	3	4	3	4	1	1	1	1	0	1	1	4	1	1
Electro chemistry	1	2	0	0	4	3	4	1	1	1	1	0	1	0	2	1	2
Thermodynamics chemistry	1	2	4	0	2	1	1	0	0	1	1	0	1	3	1	0	1
Organic chemistry	1	2	1	0	4	3	4	3	1	0	1	3	1	3	4	3	1

0, none; 1, compulsory in A; 2, selective in A; 3, higher than compulsory in A; 4, higher than selective in A

difference in the same period, such as compulsory period or election period in high school, and (b) researching difference of the breadth and depth on a specific theme.

In this part, the knowledge in compulsory course means that every student in high school has to research; the knowledge in elective course is that in science course or university course. The American curriculum standard "Science College Board Standards for College Success 2009" is applicable to elective course.

We focus on ten specific themes: (1) element compounds, (2) chemical bonds and molecule structure, (3) atomic structure, (4) reaction rate, (5) chemical equilibrium, (6) gas, (7) aqueous solution, (8) electrochemistry, (9) chemistry thermodynamics, and (10) organic chemistry. The results are based on the comparison on two sides: (a) the number of knowledge points and (b) the difficulty of specific concepts (Table 3.7).

From the table, we made four conclusions:

1. There were differences in the selection of theme. In Mainland China, "gas" is a theme studied in physics, rather than chemistry. However, in many other countries/regions, such as Taiwan, America, Canada, Korea, and Australia, it belongs to chemistry. Also, there are a lot of differences in the theme "element compounds." Mainland China, Canada, and Japan put this knowledge in compulsory course, but America, Taiwan, and Finland in election course. Even Korea, France, and Australia lack this theme.
2. There were differences in the organization of theme. In Mainland China, the knowledge in high school is organized in a spiral development process and a specific theme is studied in both compulsory and elective course. But in other countries/regions, this spiral development process is not always applied. In some themes, like atomic structure, chemical bonds and molecule structure, aqueous solution, and organic chemistry, most of these nine countries are put in this spiral development form. But themes about reaction principle such as reaction rate and chemical equilibrium are studied just in elective course.

Table 3.8 The main difference in every theme of chemistry in high school

Themes	Key point
Element compounds	Exist/nonexistent; number of represent matter
Chemical bonds & molecule structure	Dipole. Lewis structures. VSEPR model, bond energy, bond length, bond angle, electro negativity value
Atomic structure	Atomic model, electron affinity, electro negativity, ionization energy, Pauli exclusion principle and F. Hund's rule, absorption spectrum, emission spectrum
Reaction rate	Reaction order, the effect on reaction rate; surface area. Mass Action Law
Chemical equilibrium	Entropy change, Q, K: K_{eq}, K_{sp}, K_w, K_a, K_b, K_p,
Solution	K_a, buffer solution
Electrochemistry	Oxidation number, electrode potential
Chemistry thermodynamics	System and environment, Enthalpy change, Gibbs free energy
Organic chemistry	Amines and amides, different types of organic reactions

3. There were differences in the breadth and depth of theme. On this aspect, first, some countries, like America, Canada, and Taiwan, are more difficult than Mainland China generally. These can be seen from themes like "chemical bonds and molecule structure" and "atomic structure." Second, organic chemistry, the theme which is paid more attention in Mainland China, is easier than some countries because of less representational matter number. Third, in "reaction rate," "electrochemistry," and "aqueous solution," Mainland China does not have obvious advantages.
4. There were main differences in every theme. Table 3.8 shows us the main difference in every theme. According to Table 3.8, we can reflect the knowledge selection in Mainland China's curriculum.

3.4.5 The Commonalities and Trends in Senior High School Chemistry Curriculum Assessment in Terms of the Performance Expectation, the Ability, and the Assessment

Both "ability requirement" and "performance standards" illustrate levels of students' achievement. Several documents reflected the trend that integrating core ideas with competence and performance to affect curriculum assessment will promote a reform of science education. A Framework for K-12 Science Education (2011, p. 339) recommended that standards should incorporate the three dimensions (practices, crosscutting concepts, core ideas) in both content statements and performance expectations. The College Board's Science Standards for College Success (2009, p. 111) considers that "Performance Expectations describe what students should know, understand and be able to do in order to apply, as well as build and reason with, the essential knowledge that is necessary to understand the content outlined in the objective. The PEs illustrates how students engage in science practices to develop a better understanding of the objective." The Ontario Curriculum: Science (2000, p. 9) developed two sets of performance expectations. Both "ability requirement" and "performance standards" are aims at solving the problem of "assessment."

We analyzed related curriculum documents and found the results as follows:

1. Performance standard could integrate disciplinary core ideas with science practices. It describes the way in which students are expected to apply and construct science knowledge. Performance standard should be part of curriculum standard. Performance standard will include tasks, assessment standard for student performance on the tasks, and essential knowledge required to accomplish the tasks.
2. As to the demand of ability, the scientific inquiry ability was an important ability which was widely noted by many countries. We should connect the subject knowledge and the performance of students when we state the meaning of some abilities. The "core ability" had been presented, but the meaning needs to be more specific.
3. The assessment part should be specific and operational. Two practices worth learning are those of Australia and Korea. Canada uses a report card for students and parents that deserve attention.

3.5 Reflection and Discussions

This study is a prospective research based on the comparison of the chemistry curriculum standards. We discovered some exemplary features which can reflect the trends in the field of international chemistry curriculum, such as performance expectation and the demand of ability. We noticed shortcomings of curriculum setting in Mainland China and also found three elements that contribute to curriculum structure. While searching for the commonalities contents that countries/regions expect students to learn at the primary, lower secondary, and upper secondary school, this research not only construct the progress map of some core concepts but also create a new method of building learning progressions by standards analysis. Both the results of LPs and the results of breadth and depth can contribute to the curriculum content selection and organization in standards. The standards comparison can help to resolve some problems in practice, but still there are some issues worthy of reflection and discussion:

First, this study selected keywords narrowly. The nature of science has been a relatively neglected aspect of the chemistry curriculum standards in our country, which play the host role in guiding the selection and organization of curriculum content, yet this research has not done depth analysis in this area.

Second, this study mainly focused on the knowledge, while chemistry experiment, chemical STS, chemistry and technology, and chemistry and engineering lack special research.

Third, this study focused on the selection and organization of thematic chemistry content; overall organization pattern lacks analysis and research. Also this study lacked analysis presentation of the content of chemistry after it was selected and organized. Nevertheless, the study has to inform chemistry education researchers in developing high school chemistry curriculum standards.

Acknowledgments This article was from one of the Ministry of Education projects called "international comparative research of science curriculum standards" and "international prospective research of the science curriculum standards," and some standards documents were translated by Professor EnShan Liu and his team. Thanks for their work!

References

Alaska State Board of Education & Early Development. (2006). *Content and performance standards for Alaska students*(4th ed.). Available: http://www.eed.state.ak.us/standards/pdf/standards.pdf

Arizona Department of Education-Standards Based Teaching and Learning. (2005). Arizona academic content standards: Science- high school. Available: http://www.azed.gov/standards-practices/science-standard/

Board of Education Commonwealth of Virginia. (2010). *Science standards of learning for Virginia public schools*. Available: http://www.doe.virginia.gov/testing/sol/standards_docs/science/complete/stds_sciencek-12.pdf

California State Board of Education Sacramento. (2004). *Science framework for California public schools -kindergarten through grade twelve with new criteria for instructional materials*. Available: http://www.cde.ca.gov/ci/sc/cf/

College Board. (2009). *Science college board standards for college success*. Available: http://professionals.collegeboard.com/profdownload/cbscs-sciencestandards-2009.pdf

Colorado Department of Education. (2009). *Colorado academic standards: Science*. Available: http://www.cde.state.co.us/StandardsAndInstruction/GradeLevelBooks.asp

Connecticut State Department of Education. (2004). *Core science curriculum framework*. Available: http://www.sde.ct.gov/sde/cwp/view.asp?a=2618&q=320890#nextgenscience

Delaware Department of Education. (2008). *Science curriculum framework*. Available: http://www.doe.k12.de.us/infosuites/staff/ci/content_areas/science.shtml

Finnish National Board of Education. (2003). *National core curriculum for general upper secondary education intended for young people*.

Florida Department of Education. (2012). *k-12: Science standards report without access points*. Available: http://www.cpalms.org/downloads.aspx

Georgia Department of Education. (2006). *Georgia performance standards chemistry standards*. Available: https://www.georgiastandards.org/Standards/Pages/BrowseStandards/ScienceStandards9-12.aspx

Great Britain Department for Education and Employment. (2011). *The national curriculum for England. Science: Key stages 1–4*. Available: http://dera.ioe.ac.uk/id/eprint/4402

Hawaii State Department of Education. (2005). *Hawaii content & performance standards III: Science-chemistry*. Available: http://165.248.30.40/hcpsv3/search_results.jsp?contentarea=Science&gradecourse=Chemistry&strand=&showbenchmark=benchmark&showspa=spa&showrubric=rubric&Go%21=Submit

Idaho State Department of Education. (2008). *Science content standards: 8th–9th grade physical science, 11th & 12th chemistry*. Available: http://www.sde.idaho.gov/site/content_standards/science_standards.htm

Illinois State Board of Education. (1997). *Illinois learning standards: Science*. Available: http://www.isbe.state.il.us/ils/science/standards.htm
Indiana State Board of Education. (2010). *Indiana's academic standards for science*. Available: http://www.explorelearning.com/index.cfm?method=cResource.dspStandardCorrelation&id=1226
Iowa Department of Education. (2009). *Iowa core curriculum K – 12 science*. http://www.educateiowa.gov/index.php?option=com_content&view=article&id=2330&Itemid=4342
Kansas State Department of Education. (2007). *Kansas science education standards*. Available: http://www.ksde.org/Default.aspx?tabid=4697
Kentucky Department of Education. (2002). *Physical science standards*. Available: http://its-about-time.com/pdfs/ACKY.pdf
Lei Wang. (2010). Progress and reflection on the basic chemistry education curriculum reform for 10 years(second). *Journal of Chemical Education (Chinese), 5*, 22.
Maryland State Department of Education. (2000). *Maryland science content standards*. Available: http://mdk12.org/assessments/vsc/index.html
Massachusetts Department of Education. (2006). *Science and technology/engineering curriculum framework*. Available: http://www.doe.mass.edu/frameworks/scitech/1006.pdf
Michigan Department of Education. (2000). *Michigan curriculum framework science benchmarks*. Available: http://www.michigan.gov/documents/Updated_Science_Benchmarks_27030_7.pdf
Michigan Department of Education. (2010). *High school science content standards and expectations/chemistry*. Available: http://www.michigan.gov/mde/0,1607,7-140-38924_41644_42814---, 00.html
Ministère français de l'Education. (2010). Bulletin officiel de l'éducation nationale. no.4. Première année d'études secondaires Physique – Chimie Syllabus, Sophomore au lycée Physique – Chimie Syllabus, Junior dans le lycée Physique – Chimie Syllabus.
Ministry of Education, Culture, Sports, Science and Technology. (1999). *Course of study for higher secondary school: Science*. Retrieved from http://www.mext.go.jp/a_menu/shotou/cs/1320231.htm (In Japanese).
Ministry of education, Taiwan. (2008). Curriculum guidelines of general high school compulsory subjects "chemistry". Retrieved from http://www.edu.tw/userfiles/%E6%99%AE%E9%80%9A%E9%AB%98%E7%B4%9A%E4%B8%AD%E5%AD%B8%E5%BF%85%E4%BF%AE%E7%A7%91%E7%9B%AE%E3%80%8C%E5%9F%BA%E7%A4%8E%E5%8C%96%E5%AD%B8%E3%80%8D%E8%AA%B2%E7%A8%8B%E7%B6%B1%E8%A6%81(1).pdf (in Chinese).
Minnesota Department of Education. (2009). *Minnesota K-12 academic standards in science*. Available: http://education.state.mn.us/MDE/EdExc/StanCurri/K-12AcademicStandards/index.htm
Mississippi Department of Education. (2010). *Mississippi science framework*. Available: http://www.mde.k12.ms.us/curriculum-and-instruction/science/2010-mississippi-science-framework
National Center for Education Statistics, Institute of Education Sciences, U.S. Department of Education. (2009). *Highlights from TIMSS 2007: Mathematics and science achievement of U.S. fourth and eighth-grade students in an international context*. Retrieved from http://nces.ed.gov/pubs2009/2009001.pdf
National Research Council. (2012). Summary of public feedback and subsequent revisions. In H. Quinn, H. Schweingruber, & T. Keller (Eds.), *Framework for K-12 science education: Practices, cross-cutting concepts, and core ideas*. Washington, DC: National Academies Press.
New Hampshire Department of Education. (2006). *K-12 science literacy new Hampshire curriculum framework*. Available: www.ed.state.nh.us/frameworks
New Jersey Department of Education. (1998). *New Jersey science curriculum framework: Chapter 8 -The framework: Standards 1–5 (the process standards)*. Available: http://www.state.nj.us/education/frameworks/science/
New Mexico State Department of Education. (2003). *New Mexico science content standards, benchmarks, and performance standards k-12*. Available: http://www.eunice.org/education/page/download.php?fileinfo=c2NpZW5jZV9zdGFuZGFyZHMucGRmOjo6L3d3dy9zY2hvb2xzL3NjL3JlbW90ZS9pbWFnZXMvZG9jbWdyLzYzZmlsZTE3NS5wZGY=&sectiondetailid=1

New York Education Department. (2009a). *Physical setting/chemistry: Core curriculum*. http://www.p12.nysed.gov/ciai/mst/pub/chemist.pdf

New York Education Department. (2009b). *Intermediate level science: Core curriculum grades 5–8*. http://www.p12.nysed.gov/ciai/mst/pub/intersci.pdf

North Carolina, Department of Public Instruction in Science. (2004). *Standard course of research and grade level competencies k-12*.

North Dakota Department of Public Instruction. (2002). *North Dakota standards and benchmarks: Content standards science*. Available: http://www.dpi.state.nd.us/standard/index.shtm

Organisation for Economic Co-operation and Development. (2007). *PISA 2006: Science Competencies for Tomorrow's World* (Vol. 1: Analysis). Paris: OECD Publishing. Retrieved from http://www.oecd.org/edu/school/programmeforinternationalstudentassessmentpisa/pisa2006results.htm

Ontario Ministry of Education. (2000). *The Ontario curriculum grades 11 and 12 -Science*. Retrieved from http://www.edu.gov.on.ca/eng/curriculum/secondary/science1112curr.pdf

Ontario Ministry of Education. (2008a). *The Ontario curriculum Grades 9 and 10 -Science*. Retrieved from http://www.edu.gov.on.ca./eng/curriculum/secondary/science.html

Ontario Ministry of Education. (2008b). *The Ontario curriculum Grades 11 and 12 -Science*. Retrieved from http://www.edu.gov.on.ca./eng/curriculum/secondary/science.html

Pennsylvania Department of Education. (2010). *Academic standards for science and technology and engineering education k-12*. Available: http://static.pdesas.org/content/documents/Academic_Standards_for_Science_and_Technology_and_Engineering_Education_(Secondary).pdf

Singapore Examinations and Assessment Board. (2013). *GCE A-level syllabuses examined in 2013: Chemistry H1 (8872) & H2 (9647)*. Available: http://www.seab.gov.sg/aLevel/syllabus/schoolCandidates/2013_GCE_A.html

Singapore Ministry of Education. (2008). *Science syllabus lower secondary express/normal (academic)*. Singapore: Singapore Ministry of Education.

South Carolina Department of Education. (2005). *South Carolina science academic standards k-12*. Available: http://ed.sc.gov/agency/se/Teacher-Effectiveness/Standards-and-Curriculum/documents/sciencestandardsnov182005_001.pdf

Tennessee State Board of Education. (2009). *Tennessee science standards 9-12: Physical science, chemistry I, chemistry II*. Available: http://www.tn.gov/education/ci/sci/index.shtml

Texas Department of Education. (2010). *Texas essential knowledge and skills: Chapter 112. Science, subchapter C. High school 112.35. 2010–1011*. Available: http://ritter.tea.state.tx.us/rules/tac/chapter112/index.html

Utah State Board of Education. (2002).*Utah elementary science core curriculum sixth grade*. Available: http://www.uen.org/core/science/index.shtml

Utah State Board of Education. (2003a). *Utah science core curriculum seventh and eight grades*. Available: http://www.uen.org/core/science/index.shtml

Utah State Board of Education. (2003b). *Utah science core curriculum: Chemistry*. Available: http://www.uen.org/core/science/index.shtml

Vermont Department of Education. (2000). *Vermont's framework of standards and learning opportunities k-12*. Available: http://education.vermont.gov/new/html/pubs/framework.html

Victorian Curriculum and Assessment Authority. (2005). *Chemistry, Victorian certificate of education research design*. Melbourne: Victorian Curriculum and Assessment Authority.

Virginia Board of Education Commonwealth. (2010). *Science standards of learning for Virginia public schools k-12*. Available: http://www.doe.virginia.gov/testing/sol/standards_docs/science/complete/stds_sciencek-12.pdf

Wisconsin Department of Public Instruction. (2000). *Wisconsin's model academic standards for science: Science content & performance standards*. Available: http://standards.dpi.wi.gov/stn_sciintro#content

Wyoming State Board of Education. (2008). *Wyoming science content and performance standards*. Available: http://edu.wyoming.gov/sf-docs/publications/Standards_2008_Science_PDF

교육인적자원부. 2007. 한국 교육 과정 기준:과학 및 교육 프로그램
中华人民共和国教育部. 义务教育化学课程标准[M] 北京:北京师范大学出版集团 (2011).
中华人民共和国教育部. 普通高中化学课程标准(实验)[M] 北京:人民教育出版社 (2003).
台湾普通高级中学课程发展委员会、普通高级中学课程总纲修订小组、普通高级中学各科课程纲要项目小组,(台湾)教育部.《普通高级中学课程纲要》之《普通高级中学必修科目"基础化学"课程纲要》和《普通高级中学选修科目"化学"课程纲要》 (2009).
日本文部省. 中学校学習指導要領(平成10年12月)(第4節理科).日本东京:国立印刷局. Available: http://www.mext.go.jp/a_menu/shotou/cs/1320061.htm
日本文部省. 高等学校学習指導要領(平成11年3月)(第5節理科)日本东京:国立印刷局. Available: http://www.mext.go.jp/a_menu/shotou/cs/1320144.htm

Part II
Public Science Education

Chapter 4
Search for SEAMEO Young Scientists (SSYS) – RECSAM's Initiative for Promoting Public Science Education: The Way Forward

Dominador Dizon Mangao and Ng Khar Thoe

Abstract Every government strives to equip its citizens with scientific and technological literacy to meet the challenges of the twenty-first century. SEAMEO RECSAM is a regional center 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 twenty-first-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 time 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

D.D. Mangao (✉) • N.K. Thoe
SEAMEO RECSAM, Gelugor, Penang, Malaysia
e-mail: dominador_mangao@recsam.edu.my; nkt@recsam.edu.my

B. Zhang et al. (eds.), *International Conference on Science Education 2012 Proceedings: Science Education: Policies and Social Responsibilities*,
DOI 10.1007/978-3-642-54365-4_4, © Springer-Verlag Berlin Heidelberg 2014

4.1 Introduction

Science and technology is everywhere and influences every aspect of a person's life. Information explosion, recent technological breakthroughs, and scientific researches and inventions on health and medicine, agriculture, and communications technology all influence society. However, some parts of the society (with limited exposure, especially those with out-group membership of social and political communities) lack the basic understanding of the current controversial issues haunting man's existence. Among these issues are climate change, pollution and environmental degradation, genetic modified organisms, good and bad side of information and communications technology, as well as technological fallout to name a few. As a result, society's perceptions on these controversial issues are largely influenced by the prevailing perceptions dominant in their social and political communities whether they possess in-group or out-group membership. Every government must equip its citizens with scientific and technological literacy (STL) to meet the challenges of the twenty-first century. However, the responsibility to increase the awareness and understanding of the population of the current as well as relevant issues and problems should not rest only on the education sector.

Educational institutions could not fully carry out these tumultuous tasks. Hence science and mathematics institutes and centers were established to assist in educating the population through formal science education or to engage in initiatives to complement informal public science education. This article reports on the role of SEAMEO RECSAM in promoting public science education through the Search for SEAMEO Young Scientists (SSYS) Congress. The first SSYS congress was held in 1997, and since then it was conducted every 2 years with a specific theme. To date, eight SSYS congresses have been conducted and participated in by a total of 351 young scientists and 203 research projects presented. This paper presents case studies to elaborate how the SSYS Congress could bridge formal and informal science education and eventually will lead to the development of scientific literacy in the Southeast Asian region.

4.2 Research Questions

This paper seeks to answer the following questions:

1. What is the evidence of SSYS bridging formal and informal science education to promote scientific literacy?
2. What exemplary practices have been made by SEAMEO RECSAM as the organizer of the event to ensure that the public has an easy access to science education resources?

4.3 Background of SEAMEO RECSAM's Search for SEAMEO Young Scientists (SSYS): An Initiative to Promote Science Literacy in the Region

The Southeast Asian Ministers of Education Organization Regional Centre for Education in Science and Mathematics (SEAMEO RECSAM) is 1 of the 20 centers established by SEAMEO and is located in Penang, Malaysia. SEAMEO RECSAM is a regional center for science and mathematics in education in Southeast Asia mandated to enhance teachers' teaching competence through training, courses, as well as research and development activities. RECSAM organizes the "Search for SEAMEO Young Scientists" (SSYS) as a regional congress for providing a platform for intellectual and social interactions among student researchers and educators in the Southeast Asian region and beyond. It is conducted in a form of science congress/fair or exhibition for the students to share ideas and experiences as well as disseminate information related to their scientific and mathematical research pursuits.

4.3.1 Objectives of SSYS

The SSYS is envisioned as a worthy intellectual venture and an effective medium to promote lifelong scientific and mathematical values, interests, skills, attitudes, and motivation among the youth. Specifically, SSYS aims to (a) encourage research and development in science and mathematics among young learners in SEAMEO and associate member countries, (b) provide a forum for the exchange of ideas and experiences among students in SEAMEO and associate member countries, (c) provide a venue for intellectual and social interactions among students and educators, and (d) identify and give recognition to outstanding youth science and mathematics researchers.

4.3.2 The SSYS Themes

Each SSYS event year adopts a theme from which student research projects are based upon. From the first to the fourth SSYS congress, the theme delved on interactions of science, technology, and environment, while from the fifth until the eighth SSYS congress, the theme focused on education for sustainable development (ESD).

4.3.3 The SSYS Student Researchers

The SSYS delegates were composed of officially enrolled secondary or preuniversity students in the 15–19 age-groups from the SEAMEO and associate member

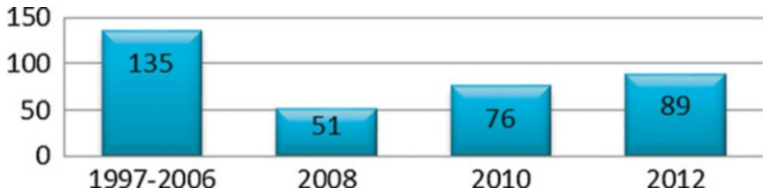


Fig. 4.1 Number of students participating in the SSYS

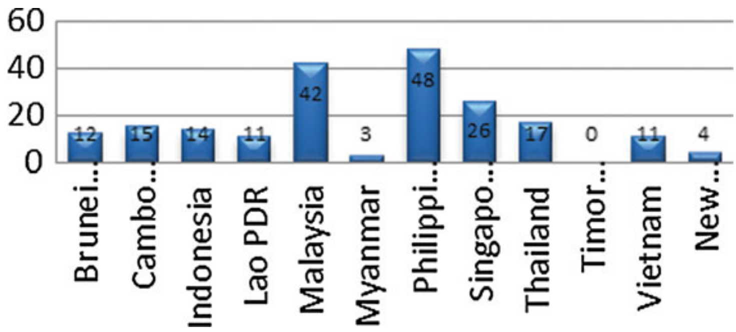


Fig. 4.2 Total number of research projects by country since 1997–2012

countries. They can join as official representative of their Ministries of Education or as fee-paying participants. The total number of student researchers participating in the SSYS for the last 12 years is presented in Fig. 4.1.

4.3.4 Number of Science and Mathematics Research Projects

The number of the research projects from each SEAMEO and associate member countries from the first SSYS to the eighth SSYS is presented in Fig. 4.2.

4.3.5 The Field of Study, Nature of Research Design, and Types of Research Samples

The students' research projects are related to the application and the integration of knowledge in basic science (biology/chemistry/physics, general science) and mathematics with technology, environment, or health. The research design employed by the student researchers in the projects may be categorized as pure experimental, quasi-experimental (controlled/uncontrolled), and nonexperimental or the observational and intervention studies (as shown in Fig. 4.3).

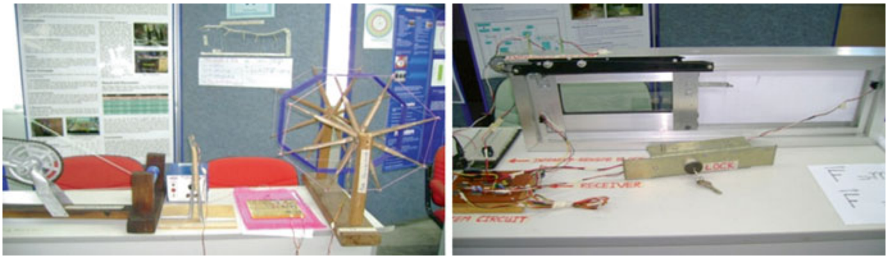


Fig. 4.3 Project exhibits with research samples

In terms of research samples, plants are frequently used as specimen in the science research projects together with other organic substances and inorganic substances as analyzed and reported by Sarmiento et al. (2006). Biological organisms and organic substances were frequently used as experimental samples for the fact that these are endemic to the community, inexpensive, and familiar to the students. Mathematics and ICT-based projects include the use of algorithm, theorem, and proof in solving problems; use of simple statistical tools in quasi-experimental research, creating geometrical figures; use of optimization in a two-dimensional structure to maximize the given space; application of Fibonacci sequence; utilizing computer modeling in wave refraction, digitizing software in getting values and shape file in GIZ software; and using software to solve problems in geometry (Mangao and Foo 2009).

4.3.6 Major Events in the SSYS Congress

The main highlight of the SSYS event is the presentation of scientific research findings of the students to their co-student researchers and to the panel of judges. The activities for the 3-day event usually include the following: (a) setting up of project exhibits, (b) a formal opening ceremony, (c) presentation of research projects to the public, (d) judging of project exhibits and interview by the judges, (e) science public forum, (f) public viewing of exhibits, (g) face-to-face and online networking session, as well as (h) awards presentation ceremony and cultural presentation.

4.3.7 SSYS Research Projects: An Initiative to Bridge Formal and Informal Science Education to Promote Scientific Literacy

Science learning should be presented in an authentic activity in a real-world situation or real context such as real-world problem solving scenario. Small-scale student

Fig. 4.4 Catfish self-feeding machine model

Fig. 4.5 Stylophora coral fragments after transplantation

Fig. 4.6 Acropora coral fragments after transplantation

research projects are means of involving young people in scientific inquiry process which will inculcate their appreciation and interest in science and eventually leads to acquisition of scientific literacy. The two case studies described below (Figs. 4.4, 4.5, and 4.6) exemplify authentic problem-based learning, project-based learning, and authentic community problem approaches which the young scientists have investigated that contributed to the development of scientific literacy.

4.4 The Case from Thailand: "Catfish Command (Self-Controlled) Feeding Machine" Science Research Project

4.4.1 Objectives of the Project

The student researchers designed and constructed a self-controlled feeding machine to provide the right quantity of feedstuff for the catfish according to their daily food requirement. In addition their investigation aimed at the following: (a) evaluate the growth performance of catfish that can withdraw its own meal in the right time and amount, (b) evaluate and observe the eating behavior of catfish, (c) determine the best model for releasing and spreading fish food, (d) determine the ideal time to be set for releasing fish food once food bait is pulled, (e) determine the capacitance value needed to generate electricity within 15 s, (f) determine the amount of feedstuff released from the machine against manual distribution, and (g) evaluate the fishpond ecosystem in terms of the physical and chemical properties of water before and after the study.

4.4.2 The Scope, Materials, and Methodology

This research project was presented during the third Regional Congress of the Search for SEAMEO Young Scientists (SSYS) in 2002. The study was conducted in the district of Kanchanadit, Surat Thani, Thailand. This experimental research was conducted in two fishponds with an area of 10 m^2 each. The water properties were evaluated prior to the start of the research with the following data: the color is green, the transparency is 12.4, the odor is relatively bad with little bubbles, and the dissolved oxygen (D0) is 1.5.

4.4.3 Summary of the Project

The researchers designed and developed a self-controlled feeding machine to provide feedstuff according to the catfish meal requirement. With the self-feeding machine, right amount of food is released on certain times of the day. This prevented feed to be wasted that would pollute the water and will cause diseases and eventual death of the catfish. Catfish in both ponds fed more when the environment is still dark and at low temperatures particularly at 6 o'clock in the morning and at 6 o'clock in the evening. They tend to eat less when the temperature is high during daytime. Catfish preferred to eat immobile or inactive baits which appeared like dead organisms. The best model to spread the fish food was through a five-prong spreading tube method.

To generate electricity in order for the microswitch to function, a 5,000-uF capacitor is needed to release fish food from the fish tanks in 15 s time interval. Though the quantity of food consumed by the catfish fed with the feeding machine was slightly higher than those fed by hands, the catfish grew heavier and longer. Moreover, the water in fishpond fed with the self-feeding machine was clearer as compared to fishpond fed using hands because there were less leftover foods observed on the surface of the water. Finally, it can be safely concluded that the use of self-feeding machine offers a host of benefits over hand-feeding such as reduced food wastage and spoilage, reduced occurrence of disease, less manpower requirement, and faster growth of catfish (Mangao and Cheah 2013).

4.5 The Case from the Philippines: "An Exploratory Study on Coral Assemblage Establishment and Artificial Reef Enhancement in the Municipal Waters of Anilao, Iloilo, Philippines, Through Coral Transplantation"

4.5.1 Objectives of the Project

The student researchers investigated whether the two Genera of corals Acropora and Stylophora coral fragments will survive and grow when transplanted in concrete artificial and bamboo artificial reefs. In addition their investigation aimed at the following: (a) determine the percentage survival of corals in the two artificial reefs, (b) determine coral transplant growth in terms of projected circular area, (c) compare coral transplant growths in different times within the 11-month period, and (d) determine water characteristics such as water temperature, salinity, transparency, and suspended solids.

4.5.2 The Scope, Materials, and Methodology

This research project was presented during the eighth Regional Congress of the "Search for SEAMEO Young Scientists" (SSYS) congress on 6–9 March 2012 from Philippine Science High School Western Visayas Campus, Iloilo City, Philippines. The study was conducted in the municipal waters of Anilao in Banate Bay, Iloilo, Philippines. The materials used in this research project were bamboos (for artificial reef), knives, pliers, copper wires, plastic trays, underwater camera, plastic slates, 1-L plastic bottles, Millipore filter paper, foil paper, dymo tape, sand bags, plastic binders, and 75×75×75-cm concrete artificial reefs. The equipment used were motorized boat, SCUBA gear and equipment, thermometer, refractometer, Secchi disk, oven, funnels, filter paper, beaker, and analytical balance. The researchers employed the following procedures in the conduct of the investigation: (a) preparation of concrete and bamboo artificial reef modules for coral transplanting; (b) collecting, preparing, and transporting of coral fragments; (c) transplanting coral fragments; (d) measuring coral length and width; and (e) calculating the projected circular area.

4.5.3 Summary of the Research Project

This study determined the percent survival and growth of Acropora and Stylophora coral fragments transplanted on 75 × 75 × 75-cm concrete and bamboo artificial reefs (AR) from February to December 2011. Percent survival of the transplanted corals after 11 months showed that Acropora transplants on concrete and bamboo artificial reefs decreased to 35 % and 15 % respectively. For Stylophora transplants, percent survival decreased to 65 % in the concrete artificial reefs and 35 % in the bamboo. Growth in terms of the projected circular area (PCA) was determined from the width and length of the coral transplants represented by the formula PCA = [(✓Length*Width)/2]2 and was compared at the beginning, first mid, second mid, and end of an 11-month period. Results revealed that mean PCA of Acropora transplants on concrete AR remained almost the same (53.2–59.7 cm^2), while those on the bamboo AR decreased with time (40.8–25.5 cm^2). Stylophora transplants grew on both concrete (63.2–121.6 cm^2) and bamboo ARs (53.9–107.1 cm^2). Other findings included the following: water temperature ranged from 29 to 32 °C, salinity was constant at 35 ppt, water transparency ranged from 2.5 to 5.6 cm, and suspended solids ranged from 0.067 to 0.152 g/L throughout the duration of the study. Finally, results of this experiment indicated that coral transplantation using Acropora and Stylophora fragments on concrete and bamboo artificial reefs is viable.

4.5.4 Forging of Partnership and Linkages with the Public

Students' science and mathematics research projects deal on authentic community real-life problems. As a result, partnerships and collaborations among the public is forged, i.e., between schools, scientists, government agencies, industries, private corporations, civic-minded persons, and philanthropists. In the Philippines, government and nongovernment institutions and agencies alike have mandates to serve the public in the so-called corporate social responsibility in advancing science education. The community being the source of the problem is also the recipient of the solutions as outcomes of research activities.

4.6 RECSAM's SEARCH: An Initiative for Public Access to Science Education and as Science Education Resources for Science Teaching and Learning

To be of service to the wider public with the aim of enhancing scientific and technological literacy in Southeast Asia and beyond, RECSAM has embarked on an initiative to create a special project to archive student research projects and made available online via a web-based learning hub or e-portal called "Southeast Asia Regional

Fig. 4.7 SEARCH e-portal

Capacity-enhancement Hub (SEARCH)" (http://www.recsam.edu.my/search/) in collaboration with public and educational partners. This online learning hub is hyperlinked to six sub-portals with two of these portals serving as a repository of the archives of student research projects made available online and may be used as resources by science and mathematics teachers. The six sub-portals (shown in Fig. 4.7 above) are (1) Search for SEAMEO Young Scientists (SSYS), (2) MAgnificent Advancement for Young Scientists (MAAYS.net), (3) Science Project/problem/programme-based Activities inCorporating Experiment MANagement (SP3ACEMAN), (4) Science Across the World (SAW), (5) Special Projects/programmes to Promote ESD and EFA (SpecP2E2), and (6) Educational Partners with Links to International Institutions (EdPartl2).

SEARCH portal serves as clearing house with links to relevant sites under this e-learning hub and invites open forum (http://forum.maays.net). Discussions could be facilitated through another sub-portal "Science Project/problem/programme-based Activities inCorporating Experiment MANagement (SP3ACEMAN) (http://sp3aceman.net) with its closed forum site (http://forum.sp3aceman.net). Both portals are available freely online and all public members are welcome to register in the forum sites to share resources uploaded onto the forum sites and participate in the open and closed forum discussions.

4.7 Conclusions

SSYS is envisioned as a worthy scientific, technological, and educational venture that enables young student scientists to investigate real-life problems in their communities and employ various research designs and other innovative methodologies to solve pressing local or community problems. Student research links the school and the public through the utilization of the resources available in the community. The e-portal "Southeast Asia Regional Capacity-enhancement Hub" (SEARCH) provides public access to informal science education and serves as instructional resources for science and mathematics teachers (Ng and Nyunt 2010). The SEARCH web-based portal provides the opportunity for educators through blended mode to learn the different themes and issues toward building networks for knowledge exchange and peer learning in public science and mathematics education in the region and beyond (Azian et al. 2010).

4.8 Recommendations

Though the objectives of the SSYS have been achieved, yet much more things need to be done. The number of research projects is still wanting as well as its quality. The Ministries of Education needs to encourage and provide more support to the science teachers so as students will have more opportunities for research activities. There is a need for stronger partnership and close collaboration of the schools with industries, institutions of higher learning, private organizations, and government agencies to tap expertise and technical assistance. Research projects which cater for sustainable development could be refined and expanded to a wider scale especially when its viability and efficiency is ascertained to enhance further its value or utility. A management system of archiving research projects into the SEARCH portal needs to be installed for ease in storing and retrieval of research projects for instructional purposes by science and mathematics teachers. I doing so, the problems of plagiarism could be avoided.

References

Azian, A., Devadason, R. P., Ng, K. T., & Wahyudi. (2010). Building networks for knowledge-exchange and peer learning in science and mathematics education within SEAMEO member countries and beyond – The role of SEAMEO RECSAM. In B. Fredriksen (Ed.), *Journal of International Cooperation in Education (JICE)* (Special Issue on 'Rethinking education aid to enhance its effectiveness: Global coordination issues in the allocation and use of education aid'). Hiroshima University, Japan: Center for the Study of International Cooperation in Education (CICE).

Mangao, D. D., & Foo, L. K. (2009, May 21–24). *Bridging the school and community through student research: The 6th SSYS experience*. Paper presented at the 14th international conference on education. Brunei Darussalam: Sultan Hassanal Bolkiah Institute of Education, Universiti Brunei Darussalam.

Mangao, D. D., & Cheah, U. H. (2013). Case studies: Benefits of student research. In C. Campbell & I. Robottom (Eds.), *Learning beyond the classroom*. Penang: SEAMEO RECSAM.

Ng, K. T., & Nyunt, K. A. K. (2010, May 17–20). *The development of an on-line learning hub in SEARCH for youth science and mathematics researchers*. Paper presented in global learn 2010 conference. Parkroyal Hotel, Penang.

Ng, K. T., Toh, L., & Boey, M. L. (2010, November). Exemplary practices in SEARCH for youth science and mathematics researchers (series 1): 'Science across the world' (SAW) programme. In *Learning Science and Mathematics* on-line journal. Issue 5, pp. 1–x. SEAMEO RECSAM. http://www.recsam.edu.my/lsm/index.htm

Sarmiento, C. Q. S., Ng, K. T., Cheah, U. H., & Wahyudi. (2006, December 6–8). *Content analysis of youth scientific programme: An RCE innovative and integrated approach for sustainable development among SEAMEO member countries*. Paper presented and compiled in proceedings of 10th APEID international conference "learning together for tomorrow: Education for sustainable development". Imperial Queen's Park Hotel, Bangkok. Retrieved from http://www.unescobkk.org/education/apeid/apeid-international-conference/10-th-apeid-international-conference/programme/concurrent-sessions/

Chapter 5
Structure of Student Interest in Science and Scientific Literacy: Using the Latent Class Analysis

Takuya Matsuura

Abstract This study explored the latent class of the structure of Japanese students' interest in science and scientific literacy based on the result of PISA2006. As the result of this analysis suggested, Japanese students could be divided into two latent classes that differed in terms of the direct effect of instrumental motivation to learn science (F6) on scientific literacy (F7).

Keywords PISA2006 • Scientific literacy • Latent class • Interest in science

5.1 Introduction

As the results of PISA2006 (OECD 2007) and other international assessments have been realized, there were concerns in Japan that although students showed high score of scientific literacy, their interests in science were low (NIER 2007). This study was conducted on the latent class of the structure of Japanese students' interest in science and scientific literacy using structural equation modeling (SEM). The data set (JPN, $N = 5{,}952$) of this study was from the Programme for International Student Assessment (PISA) 2006.

5.2 Method

In the analysis model, the six constructs of interest in science used were as follows: enjoyment of science (F1: ENJ, five items), general value of science (F2: GEV, five items), personal value of science (F3: PER, five items), future-oriented motivation

T. Matsuura (✉)
Graduate School of Education, Hiroshima University, Hiroshima, Japan
e-mail: takuyam@hiroshima-u.ac.jp

B. Zhang et al. (eds.), *International Conference on Science Education 2012 Proceedings: Science Education: Policies and Social Responsibilities*,
DOI 10.1007/978-3-642-54365-4_5,

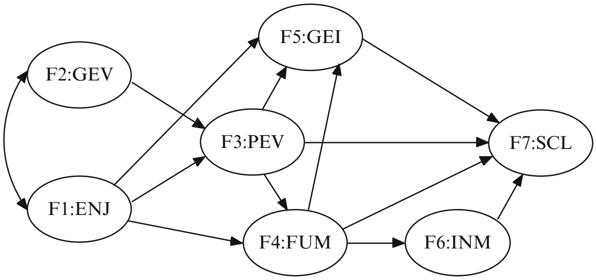


Fig. 5.1 Model of latent class analysis

to learn science (F4: FUM, four items), general interest in science (F5: GEI, eight items), and instrumental motivation to learn science (F6: INM, five items). On the other hand, scientific literacy (F7: SCL) included the following: student performance in identifying scientific issues, explaining phenomena scientifically, and using scientific evidence. For the analysis model, the six constructs of interest in science (F1–F6) were used as the predictive factors that affect to F7 (SCL) (see Fig. 5.1); the hypothesis was that effects of F4 (FUM), F5 (GEI), and F6 (INM) to F7 (SCL) are different between the latent classes.

5.3 Results and Discussion

As the result of this latent class analysis (LCA) estimated by Mplus (Muthén and Muthén 2010), model fit information criteria indicated the existence of two latent classes (N: class 1 = 953, class 2 = 4,999). The total effects of F4 (FUM) and F6 (INM) at class 1 (M = 633, F = 320) were stronger than class 2 (M = 2,370, F = 2,629). The key difference of the two latent classes was the direct effects from F6 (INM) to F7 (SCL) in that class 1 was larger than class 2. Mean values of all constructs (F1–F7) of class 1 were higher than class 2. These results indicated heterogeneity of Japanese students, so we need to consider the differences when we try to enhance the relationship between science interests and literacy.

References

Muthén, L. K., & Muthén, B. O. (2010). *Mplus user's guide* (6th ed.). Los Angeles: Muthén & Muthén.

National Institute for Educational Policy Research (NIER). (2007). *Ikiru-Tameno Chishiki-to-Ginou 3: OECD Seito-no-Gakusyu-Toutatsudo-Chousa (PISA)* (in Japanese). Tokyo: Gyousei.

OECD. (2007). *PISA 2006: Science competencies for tomorrow's world vol. 1 – Analysis*. Paris: OECD.

Chapter 6
The Tentativeness of Scientific Theories: A Study of Views from Different Educational Levels in Malaysia

Jasmine Jain, Nabilah Abdullah, and Beh Kian Lim

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. 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 et al. J Res Sci Teach 39(6): 497–521, 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 views on the way Malaysian students perceived the nature of scientific theories compared to their counterparts in other countries.

Keywords Nature of science • Scientific literacy • Malaysia • Tentativeness

J. Jain (✉) • N. Abdullah • Beh K.L.
Faculty of Education, Universiti Teknologi MARA Malaysia, International Education Centre (InTEC), Campus Section 17, Section 17, Shah Alam 40200, Selangor, Malaysia
e-mail: jasmynjain@gmail.com

B. Zhang et al. (eds.), *International Conference on Science Education 2012 Proceedings: Science Education: Policies and Social Responsibilities*,
DOI 10.1007/978-3-642-54365-4_6,

6.1 Introduction

"Change is the only constant" was rightfully mentioned by the Greek philosopher, Heraclitus (c.535 BC–475 BC), as changes can be overtly seen in the overwhelming development of the world now. With the vast technologies currently available, science knowledge known to human has experienced this exponential growth. The same vein was quoted by Einstein when he postulated the expansion of the universe. Everything is capable of change in this highly digitalized world, scientific knowledge included. The dynamic science epistemology is an ongoing process of inquiry. Therefore, understanding science by its structure alone is detrimental to science learners. For example, just by memorizing and knowing scientific explanations to phenomena is insufficient for learners. Other than the structure, the developments and characteristics should also be made known to the learners. It includes how theories were developed and the limitations of theories in scientific epistemology. These, according to many reform documents, are the criteria to achieve science literacy through the understanding of the nature of science. This paper shares the findings obtained from a doctoral research conducted in Malaysia which looked at the views on the following aspects among students across different educational tiers:

- The tentativeness of scientific theories
- The relationship between scientific theory and law
- The aim of experiments in science
- The structure of experiments in science

However, only the findings gained from the aspect of tentativeness of scientific theories are discussed in this paper.

6.2 The Nature of Science

Science literacy has been dominating the aims of global science education since the last centuries. Many efforts were carried out in search for the panacea to make science learners to be truly science literate. One of the ways suggested by the academia was to make the students comprehend the nature of science (hereafter, written as NOS). NOS was believed as able to develop learners' competence in science-based decision making (Parker et al. 2008). From the literature surveyed, the definition widely cited in the area of NOS is the one offered by Lederman (1992). According to him, NOS simply refers to the epistemology of science or how science is done. NOS as a concept was defined similarly in a study conducted by Lin et al. (2002) to compare improvements in science understanding between the NOS-informed students with their counterparts who have uninformed views on NOS. It was revealed that students who have better and informed views of NOS performed better compared to those who perceived science as static body of knowledge. Similarly in Malaysia, the aim of achieving science literacy through understanding NOS among the Malaysian science learner can be identified through the objectives delineated by Curriculum Development Centre in Malaysia (Ministry of Education 2005). It was overtly reflected through these aims listed in the 11 objectives of science education as quoted below:

> 2nd objective: Understand developments in the field of science and technology.
> 10th objective: Realize that scientific discoveries are the result of human endeavor to the best of his or her intellectual and mental capabilities to understand natural phenomena for the betterment of mankind. (Ministry of Education 2005, p. 2)

As the facets of NOS include those of sociology, history, philosophy, and psychology, there have been contradictory views on what should be incorporated into NOS. A helpful consensus on what constitutes the NOS was however inferred by Lederman (1992). He distinguished few aspects of NOS which are relevant and made known to the students for the sake of developing their science literacy (Lederman and Niess 1997; Loving and Cobern 2000). These consensuses are enumerated, among others, as follows: (a) tentativeness of scientific theories, (b) empirical basis of science, (c) subjectivity of science, (d) creativity in science, (e) social and cultural embeddedness of science, (f) observation and inferences, and (g) theories and laws. Although the facets of NOS are numerous, this study intended to study students' conceptions only on one aspect, namely, the tentativeness of scientific theories.

6.3 The Problem

Due to the importance of comprehending NOS, there have been a substantial number of research conducted in looking at how it can be improved. The attempts have been done at numerous levels, ranging from elementary school learners to professors and scientists in the similar field (Walls 2009; Keiser 2010; Ochanji 2003; Karakas 2006; Jones 2010). All of the studies quoted were studies conducted outside of Malaysia. In Malaysia, there have been a few similar studies done looking at the understanding of the NOS (Nyanasekaran 2004; Eng 2002; Sathasivam 2002). However, all of the studies only used the Nature of the Scientific Knowledge Scale (NSKS) as instrument of their study (Rubba and Anderson 1978). As a basis of comparison, the researcher will only discuss the reported percentage of "developmental" subscale of their findings. This is because Rubba (1977) characterized the "developmental" subscale as similar to the aspect under study of this paper. Rubba described the "developmental" subscale as "scientific knowledge is never 'proven' in an absolute or final sense. It changes over time. The justification process limits scientific knowledge as probable" (Rubba 1977, p. 3). In looking at the local findings of the "developmental" subscale discovered by Nyanasekaran (2004), it was revealed that the percent mean score among the Form Five technical students of Perak state of Malaysia was 57.8 %. Eng (2002), on the other hand, who studied the NOS understanding among Form Six students in Sarawak obtained a lower mean score of

52.7 %. Similar studies were also carried out by Sathasivam (2002) who looked at NOS understanding among the preuniversity students in Kuala Lumpur. This study revealed somewhat a similar percent mean score on "developmental subscale" which was 78.1 %. All the study reported herein used only NSKS as instrument. A traditional instrument such as this has been criticized for forcing the choices upon the respondent, and there is a probability of respondents interpreting the items differently from the item developer (Alters 1997). This suggested a gap to be filled by this study, in which the respondents' understanding on NOS was probed through interviews, offering more in-depth insights on their present understanding of the NOS. Moreover, this study focused on the difference of their conceptions on the tentativeness of scientific theories across different educational tiers.

6.4 The Study

This study intended to look at the conceptions of students from different educational levels with regard to the tentativeness of theories in science. The subjects of this study were students purposively drawn from their respective educational tiers, namely, secondary two (aged 14), secondary four (aged 16), and post-matriculation students (aged 19). There were 27 respondents who participated in this study with equally nine students in each tier. All students were either studying in the science stream (secondary four and post-matriculation) or taking up fundamental science subject (secondary two) in Selangor, Malaysia. In this study, lower secondary students (first tier) were indicated by LR, upper secondary students (second tier) as UR, while post-matriculation students (third tier) were given the acronym MR. The number that follows after the acronym was used to indicate the different respondents. For example, MR1 referred to the first respondent from the post-matriculation level.

The methodological approach adopted for this study was phenomenography. This was deemed appropriate as the study aimed to investigate the "qualitative different ways" (Marton 1981) people may have on a phenomenon. Although there are variations in thinking, Booth (1994) clearly explained that the similar salient features exist and can be grouped together under few categories. Following this methodological framework, they were interviewed individually by the researcher in order to gain in-depth understanding on how they perceived theories in science. The interviews were semi-structured, guided by the questions adopted from VNOS(C) which were intended to infer their conceptions on nature of scientific theories (Lederman et al. 2001). The questions were as follows:

After scientist has developed a scientific theory (e.g., atomic theory, kinetic theory), does the theory ever change?

1. If you believe that science theory does not change, explain why. Can you please provide an example on that?
2. If you believe that a theory change, explain why they change?

The validity of their conceptions was revised by looking at the consistency of their explanations and their responses when instances stating theories in science were given during the interview. The finding was also member checked (Buchbinder 2011) to reduce the possibilities of biasness.

6.5 Findings and Discussion

The iteration analysis of the transcribed data from the different tiers revealed that there were four major ways whereby the students looked at the nature of theory in science. They were as follows: (a) theory is static; (b) theory is book static; (c) theory is conditionally tentative; and (d) theory is tentative.

6.5.1 Scientific Theories Are Static (C1)

Students expressed the notions that theories in science are real and were discovered by scientists. They coined the words such as "truth" and "facts" to be associated with scientific theories while explaining their understanding. This is a common finding which have been reported by other studies as well, claiming that students have inadequate understanding on the nature of scientific knowledge (e.g., see Liang et al. 2008). The responses that reflected this thinking were grouped under this category as exemplified below:

> UR10: "teori takkan berubah pada masa depan sebab dia kebenaran. kita belajar teori untuk tahu macam mana benda tu terjadi" [Theories will not change in the future because it is the truth. We are learning theories to understand how things happen.]

According to this respondent, theory describes the truth about what is happening around him. All the respondents grouped under this category felt that theory gave account of objectivity in science. However, the psychological notion (Hodson 1986) noted that biasness in science is always present as scientists are like other human beings who hold myriad biasness about how the environment and world operate. Therefore, science is never objective.

6.5.2 Scientific Theories Are Book Static (C2)

Differing subtly from the previous category, these responses grouped under this category expressed views in which only theories in books are real. They disregarded the rest by referring that the truth of those out-of-book theories is still questionable. For example, UR1 who learned Bernoulli theory from his book recently said that the particular theory is true. However, this property of theory being true excludes other theories which were not able to be proven. Quoting UR1:

> "Kalau dapat dibuktikan, dia dah jadi macam benar. Tapi sebab kat dunia ini kan banyak lagi yang tak boleh dijelaskan dalam sains [paused]..macam teori Bernoulli tu, memang orang dah sure betul, cuma macam teori-teori yang lain" [If it can be proven, then it is real. But due to the many scientifically unexplainable things in this world [paused].. Bernoulli theory for example, people are sure that it is true, it's just that other theory which is not proven.]

The students were drawing distinction between theories learned and not learned by them. They displayed a more convinced view toward theories in book because the experimentation-laden contents can be explained well with the use of theories. Therefore, the respondent felt that experiments prove the theories real and, hence, confirmed them. A response by UR8, quoted as follows, reflected this view:

> "Ada [teori] yang kekal dan tak kekal. teori yang kekal ini telah dibuktikan dengan membuat eksperiment. Teori yang tak betul, kita cari apa yang tak kena dengan…membuat eksperiment… Teori dalam buku sudah melalui eksperimen, sudah betul and we learn something which is right" [There are changeable and unchangeable theories. The unchangeable one has been proven through experiments. For the incorrect theories, we have to look for what is wrong by conducting experiments on it. Those theories in books have been experimented, are true and we are learning something which is right.]

The responses gained about theories under this category reflected the thinking in which only certain theories are true and static, while others are changeable. Other than that, the true theories are only confined to the context of theories in the printed form learned by them. This might be due to the nature of the term "theory" used in the layman's term, suggesting that theory is an idea subjected to change (Wartofsky 1968). However, the evidences and data that science is able to provide and explain through their experience contradicted with their notion of "theory" as understood by them in layman's term. Therefore, they try to accommodate both ideas and form a notion whereby "theories are book static." This explained why the respondents were not able to provide answers when asked to explain any theory out of the book that they know of.

Although responses under this category depicted ideas that theories are static (as to the previous category), to some extent, however, they are different as they also held conception that theory is tentative. Therefore, the researchers felt that it is necessary to group them under a different category.

6.5.3 Scientific Theories Are Conditionally Tentative (C3)

The conceptions under this category firmly viewed that theories in science are tentative, only when it meets certain conditions. They perceived that theories can be tentative if and only if the conditions imposed as mentioned by them were met. The conditions listed by the respondents vary from one respondent to the others. Few respondents felt that drastic environmental change or the changes to the world in future can cause a scientific theory to change. When asked to explain why theories change, MR6 said:

> "Boleh [berubah] sebab sains ni banyak pasal enviroment. jadi kalau environment berubah, kemungkinan teori yang akan datang pun berubah. Contohnya iklim, global warming…so teori akan berubah" [They can change because science is mostly about environment. So if environment changes, the theories will then change. For example, weather, global warming…therefore, theory changes.]

MR7 provided more detailed explanation on why she thinks theories change. She described the factor of change as follows:

> "Faktornya, saya rasa dari segi biologi la kan, dunia ni sendiri la. In our planet kan, saya rasa semua benda boleh berubah. dari segi cuaca, from tahun-tahun dulu sehingga sekarang kan, dia punya suhu, environment kan dah lain. Itu dari segi biologi"[In this world itself, and from biological perspective, I feel that everything is capable of changing. Compared to ages before, weather, temperature and environment now are different.] (MR7)

MR1 provided views which were included in both "conditionally tentative" and "book static" categories. This particular respondent provided the following account:

> "Perubahan teori bergantung pada evolusi, atau kejadian tu berubah. Benda dalam buku tu betul…tak mustahil benda tu berubah pada masa depan. Macam pertukaran suhu, kejadian mahkluk tu, macam zaman dinasor, dia akan pupus." [Theory's change is dependent on evolution, or the changes of any events. The things in the book are true, but it is not impossible that it will change in the future. Like temperature change, existence of beings, like dinasour's age, they extinct.] (MR1)

From all the responses above, the condition they imposed on the theories is "theories can only change when there is a drastic environmental or world change." Other than environmental changes, there were also responses which viewed that only minor changes can happen to a theory if changes take place. These respondents felt that theories are improvised and refined from the previous theories by undergoing minor and partial alterations. When posed with the question whether a theory changes or not, the responses as included below reflected the respondents' conceptions in which the new theory must be a derivation of the former ones. The condition they imposed on theory here is "theory can only undergo minor alteration if they are to be changed." When asked why they think theory changes, one of the responses provided was:

> "Tapi dari segi dia nak ubah teori tu, mesti lah modify the teori kan? Dia bukan ubah semua masa dia modify tu..macam ada term-term dia cancel out je." [But as for the way for a theory to change, it must be modifying another theory right? It is not changing the whole theory, but modifying it…it is like cancelling out certain terms only.] (MR7)

UR5, too, brought a similar notion about the modification of theories to the fore, adding that it can happen with the continuous effort by scientists to discover new things:

> "Ahh. [teori] boleh berubah jika ada saintis lain yang cuba *explore* benda baru..mungkin [teori itu] tak [berubah] semua tapi sikit-sikit" [Theory can change if there are other scientists who try to explore something new. Not overall change but just a little change.]

Despite the thinking that scientists discover new things and cause the theory to change, this particular respondent still felt that a theory can only be altered, hence placing a constrain for a theory to change as a whole. This is identical with a condition as imposed by the students discussed earlier. Another similar view was described by UR9 in the following account:

> "Maybe can change in the future. Dia dah tetap, tapi akan ditokok tambah pada masa depan. Mungkin pada masa depan, teknologi menjadi semakin canggih, jadi teori berubah dari masa ke semasa" [Maybe can change in the future. It is fix [but] it can be added on in the future. Maybe in the future, technologies become more advance, so theory changes from time to time.]

This response inferred a conception as perceived earlier by UR5. However, this particular student implied the advancement of technology as a factor that caused the modifications to theories.

From the above responses, it is no doubt that advancement of technologies is able to propel the development of scientific knowledge. With the technological aid, many gadgets and devices can be invented to allow the scientists to have better techniques and more careful observations. Inferring from the responses grouped under this category, the theories can change if:

1. Drastic environmental change happens
2. There is technological advancement
3. Changes only involve minimal modification of theories

The responses in this category reflected the thinking that their ideas about the theory change in science was different from what have been perceived by scientists. Their interpretation of changes in science reflected their world as they see it, in which they made references to the physical features of the world. They mentioned "global warming," "evolution," "weather," "temperature," and "extinction" as environmental features that change theories. However, it is unnecessary that the theories in science changes only with the change in environment and new discoveries by scientists. As Thomas Kuhn (1970) concurred, the theories and ideas in science are very much influenced by the scientists and research paradigm. Even looking at the same data adopting a different paradigm is capable of changing the whole network of theories in science. It is not solely caused by new discovery and the changes may not necessarily be improvised, altered or developed from an earlier theory. In a similar vein, the changes in the environment do not affect the changes of theory. This is because theory is able to withstand although being tested at a different time or place due to its predictive power. For example, the theory of gravitation can be implied to anticipate the movements of the moon or other planets or in predicting the falling of objects 100 years ago.

6.5.4 Theories Are Tentative (C4)

Another less frequent, yet distinctive category under this aspect is the notion that theory in science is tentative. They viewed science as an epistemology which does not have a dichotomous right and wrong answer. Science, to them, is an endeavor in understanding the world. The feedback by MR3 was among the responses gained reflecting this notion:

> "Teori tu macam hipotesis. benda tu tak dapat dibuktikan. contoh macam.. Teori Darwin tu kan, cikgu saya kaitkan bahawa teori ini berkaitan dengan evolusi, yang manusia bermula dari monyet kan. tapi takda pun fosil manusia yang dijumpai dalam bentuk fosil monyet. jadi theory ni satu prediction ah…tak dapat dibuktikan lagi" [Theories are like hypothesis. It cannot be proven. For example, Darwin's theory of evolution, that human originated from apes. But there are no human fossils which were found to be similar as monkeys' fossils. Therefore, theory is like a prediction, still have not been proven.]

MR3 conception was largely influenced by his former teacher, quoting the evolution theory by Darwin. He also mentioned that theory is just a prediction and hypothesis which has not been proven. Hence, theory can change with time. Theory, to him, is therefore tentative. MR10, on the other hand, provided an example emphasizing on the different ideas that scientists have, as follows:

> "Boleh berubah…mungkin teori tu tak salah tapi mungkin benda tu ada sifat-sifat yang berlainan dan saintis A tak jumpa tapi saintis lain jumpa. jadi benda tu tak salah, cuma mereka ada pendapat masing-masing"[Changeable. The theory might not be wrong but maybe there are different facets of it which scientist A might not discover, but it's discovered by other scientists. It doesn't mean that scientist A is wrong but it's just that they have different opinions.]

To MR10, the differences in scientists' views cause the change in the theory as the theory proposed by a scientist might be altered by other scientists who look at the same problem differently. This particular respondent captured the idea that there is no absolute truth in science, suggesting that theories are always tentative. MR4, on the other hand, felt that technology played a bigger role in causing a theory to change. He provide following explanation:

> "Theory can change with time…theory ini early prediction. so it is not impossible for theory to be changed in the future…dengan kecanggihan teknologi yang ada pada sesuatu masa itu, dengan kajian yang dijalankan lebih terperinci, boleh menyebabkan theory berubah"[Theory can change with time…theory is an early prediction. so it is not impossible for theory to change in the future…with the present advancement of technology and specific investigations, theory can change.]

To MR4, advanced technology enabled investigation to be conducted in scrutiny, allowing more discoveries to be made as more things can be observed with better tools and techniques. MR4, however, felt that theory is able to change as it is an early prediction. Hence, the notion "theory is tentative."

Although the three respondents were able to display adequate idea on the tentativeness of scientific theory, it lacked of inherent sound understanding on the term "theory." They perceived that theories are like hypothesis or predictions. However, theory and hypothesis or prediction should not be used interchangeably. The hypothesis mainly is regarded as prediction used in experiments, while theory, although tentative, is an idea which is durable as it has withstood numerous testing against it. This misconception too has been reported as a pervasive myth by McComas (1998).

6.6 Outcome Space

Outcome space is established in the pursuit to provide an overview in regard to the dimensional and structural aspects for each category that emerged (Marton 1981). This also provides clarification of framework on the various ways the respondents of this study perceived theories in science. However, clarification in regard to the categories found across tiers and its frequency is first elaborated to guide the readers in understanding the outcome space.

Analyzing the views across levels as depicted in Fig. 6.1, it appeared that only students in the third tier were able to see science as a dynamic knowledge. However, there were few students in the same level who imposed conditions for changes to happen on theories, and it was found that the conditions listed by students in the third tier were more than their counterparts in the second tier. Students in the lowest tier, too, articulated similar notion on the restrictions for the theories to change, but it was observed that there were less pauses and doubts in responses from the respondents in highest tier. On the other hand, they were faster in providing examples and were confident with the answers they provided when asked by the interviewer. For respondents from the lowest tier, they tend to have more naive views in science, with the nature of scientific theory revolving around the notion of absolute and objectivity of science. Besides that, they also perceived that the notion of "science knowledge available in book is static." This existed in the second tier too, in which they reckoned that "theories in books are proven already." The conception that science is of absolute truth was identified to be existing among the students of the first and second tiers.

Figure 6.2 illustrated the conceptions as perceived by the respondents based on the frequencies found, indicated by the number of times the notion reflecting the categories were mentioned or inferred by respondents. Higher frequency of a category suggests more stable ideas in looking at the tentativeness of theory across the educational tiers. As human minds are actively constructing ideas in the effort to understand the world through their experience (Applefield et al. 2001), participants held a range of descriptive ideas about the nature of theories in science. Hence, they provided more than one idea that can be categorized under distinctive categories.

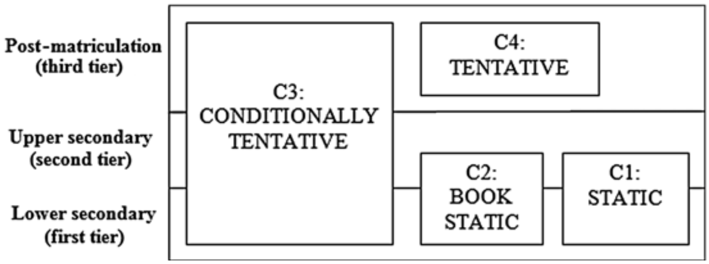


Fig. 6.1 Categories of description emerged across the multiple educational tiers

Increasing frequency →

	C1: STATIC	C4: TENTATIVE	C2: BOOKSTATIC	C3: CONDITIONALLY TENTATIVE
First Tier	2	0	3	6
Second Tier	2	1	4	4
Third Tier	0	7	0	5

Fig. 6.2 Categories of description emerged according to the frequency

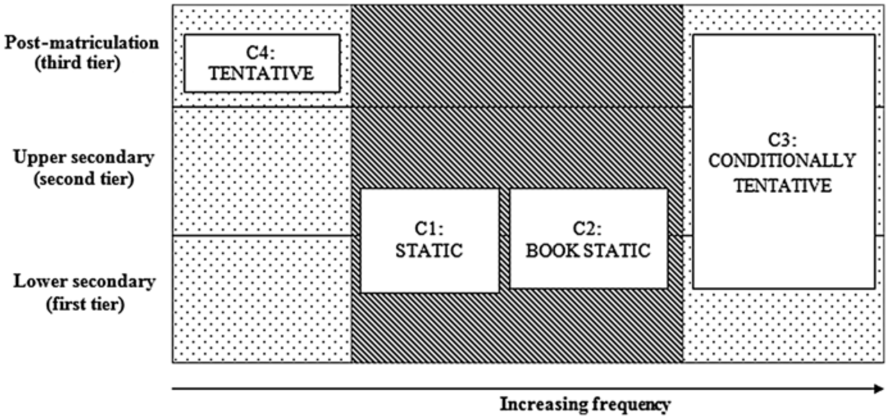


Fig. 6.3 Outcome space for the descriptive categories of "tentativeness of theory in science"

The term "frequency" used here is similar to the term "completeness" as coined by Keiser (2010) which he referred to as more stable conceptions, inferring categories which are commonly found and appeared to be more dominant compared to other categories. However, the researcher used the term "frequency" here to indicate the number of categories inferred by respondents, which is believed to be clearer to the readers in interpreting the outcome space later.

Figure 6.3 is the outcome space derived by blending both Figs. 6.1 and 6.2 above as the dimensional structure of the categories emerged. It displayed the relationships between the categories and how the categories existed across the different educational tiers. The figure suggested that the most stable idea contributed by respondents was "Scientific theories are conditionally tentative." The different patterns of backgrounds, on the other hand, distinguish categories which were not logically related as compared in the phenomena. Categories C1 and C2 were placed in a similar background to highlight the similarities between them, i.e., the belief that theories can never change. Similarly, C3 and C4 categories were placed in the same background to illustrate that both categories reflect the similar notion which believed that theories are subjected to change. The outcome space also indicates that the participants held a range of distinctive conceptions over time, with the categories "conditionally tentative" consistently appeared across the different levels in this case.

Although this study was conducted qualitatively and cannot be generalized, it suggested that students have even more complicated views about the nature of scientific theories. A vast amount of research categorizing students' views as informed and uninformed (Akerson and Hanuscin 2007; Dogan and Abd-El-Khalick 2008; Khishfe 2008) does not assist in understanding these views better. The findings of this study revealed that besides the students' uninformed views (theory is static) and informed views (theory is tentative), there also existed different ways in which the tentativeness of science knowledge is viewed. These are the blend of both "informed" and "uninformed" views.

6.7 Conclusions

The findings of this studies provided different insights on students' perspectives of the scientific theories. The researcher believed that the reasoning of the answers provided by the respondents is important because it served as the departing point in which their conceptions can be corrected. This is also critical as the point of information while tailoring the explicit reflective instructions to the learners. This research can be furthered extended to identify the notions of more students from different education levels in order to gain a clearer understanding on their views. Actions can therefore be taken to assist learners in understanding NOS, or else the efforts in developing the global science literacy will fall short.

References

Akerson, V. L., & Hanuscin, D. L. (2007). Teaching nature of science through inquiry: Results of a 3-years professional development program. *Journal of Research in Science Teaching, 44*(5), 653–680.

Alters, B. J. (1997). Whose nature of science? *Journal of Research in Science Teaching, 34*(1), 39–55.

Applefield, J. M., Huber, R., & Moallem, M. (2001). Constructivism in theory and practice: Toward a better understanding. *The High School Journal, 84*(2), 35–53.

Booth, S. (1994). *On phenomenography, learning and teaching*. Paper presented at the phenomenography: Philosophy and practice conference, Brisbane, 7–9 Nov 1994.

Buchbinder, E. (2011). Beyond checking experiences of the validation interview. *Qualitative Social Work, 10*(1), 106–122.

Dogan, N., & Abd-El-Khalick, F. (2008). Turkish grade 10 students' and science teachers' conceptions of nature of science: A national study. *Journal of Research in Science Teaching, 45*(10), 1083–1112.

Eng Guan Guch. (2002). *The understanding of the nature of science and its relationships with cognitive level, science major and academic achievement of form six science students.* Unpublished master's dissertation, Universiti Malaya.

Hodson, D. (1986). The nature of scientific observation. *School Science Review, 68*, 17–28.

Jones, W. I. (2010). *Examining pre service science teacher understanding of nature of science: Discriminating variables on the aspects of nature of science*. Doctoral dissertation. ProQuest database. UMI Number: 3435700.

Karakas, M. (2006). *College science professors' understanding and use of nature of science*. Unpublished doctoral dissertation, Syracuse University. ProQuest database. UMI Number: 3251773.

Keiser, J. C. (2010). *Identifying variations in thinking about the nature of science: A phenomenographic study*. Doctoral dissertation. ProQuest Database. UMI Number: 3408404.

Khishfe, R. (2008). The development of seventh graders' views of nature of science. *Journal of Research in Science Teaching, 45*(4), 470–496.

Kuhn, T. (1970). *The structure of scientific revolutions* (2nd ed.). Chicago: The University of Chicago Press.

Lederman, N. G. (1992). Students' and teachers' conceptions of the nature of science: A review of the research. *Journal of Research in Science Teaching, 29*, 331–359.

Lederman, N. G., & Niess, M. (1997). The nature of science: Naturally? *School Science and Mathematics, 97*, 1–2.

Lederman, N. G., Schwartz, R. S., Abd-El-Khalick, F., & Bell, R. L. (2001). Pre-service teachers' understanding and teaching of nature of science: An intervention study. *Canadian Journal of Math, Science & Technology Education, 1*(2), 135–160.

Liang, L. L., Chen, S., Chen, X., Kaya, O. N., Adams, A. D., Macklin, M., & Ebenezer, J. (2008). Assessing preservice elementary teachers' views on the nature of scientific knowledge: A dual response instrument. *Asia- Pacific Forum on Science Learning and Teaching, 9*(1), article 1. Retrieved January 19, 2011, from http://www.ied.edu.hk/apfslt/v9_issue1/liang/index.htm

Lin, H. S., Hung, J. Y., & Hung, S. C. (2002). Using the history of science to promote student's problem solving ability. *International Journal of Science Education, 24*(5), 453–464.

Loving, C. C., & Cobern, W. W. (2000). Invoking Thomas Kuhn: What citation analysis reveals about science education. *Science and Education, 9*, 187–206.

Marton, F. (1981). Phenomenography – Describing conceptions of the world around us. *Instructional Science, 10*, 177–200.

McComas, W. F. (1998). The principal elements of the nature of science: Dispelling the myths. In W. F. McComas (Ed.), *The nature of science in science education: Rationales and strategies* (pp. 53–70). Boston: Kluwer Academic Publishers.

Ministry of Education. (2005). *Curriculum development centre: Integrated curriculum for secondary schools curriculum specifications chemistry form 5*. Retrieved March 2, 2011, from http://www.moe.gov.my/bpk/sp_hsp/sains/kbsm/hsp_chemistry_frm5.pdf

Nyanaseakaran Sivaratnam. (2004). *Technical students' understanding of the nature of science and its relationships with academic achievement and gender*. Unpublished Master's dissertation, Universiti Malaya.

Ochanji, M. K. (2003). *Learning to teach the nature of science: A study of pre service teachers*. Unpublished PhD dissertation, Syracuse University. ProQuest database. UMI Number: 3099526.

Parker, L. C., Krockover, G. H., Lashertrapp, S., & Eichinger, D. C. (2008). Ideas about the nature of science held by undergraduate atmospheric science students. *Bulletin of the American Meteorological Society*. Retrieved December 12, 2010, from ProQuest database.

Rubba, P. A. (1977). *User's manual for the nature of scientific knowledge scale*. ERIC document ED 146225.

Rubba, P. A., & Andersen, H. (1978). Development of an instrument to assess secondary school students' understanding of the nature of scientific knowledge. *Science Education, 62*(4), 449–458.

Sathasivam, R. (2002). *Pre-university science students' understanding of the nature of science and its relationship with academic achievement and gender.* Unpublished Master's dissertation, Universiti Malaya.

Walls, L. (2009). *A critical hermeneutic study: Third grade elementary African American students' views of the nature of science.* Unpublished PhD thesis, Purdue University. ProQuest Database. UMI Number: 3378910.

Wartofsky, M. W. (1968). *Conceptual foundations of scientific thoughts: An introduction to the philosophy of science*. London: The Macmillan Company.

Chapter 7
The Study of Koreans' View of Nature

Yumi Lee and Yeon-A Son

Abstract Science is an activity based on the wonders of what happens in nature. The process of theorizing and organizing natural phenomena is 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 human beings as one with nature. 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

7.1 The Necessity and Purpose of the Study

Science is the activity based on the wonders of what happens in nature. According to Cobern (1991), "each person has a fundamental, epistemological macrostructure which forms the basis for his or her view of nature" (p. 4). The process of theorizing and organizing natural phenomena is affected by the view of nature.

Y. Lee (✉)
Chongryang Elementary School, Seoul, South Korea
e-mail: krmutine@nate.com

Y.-A. Son
Dankook University, Gyeonggido, South Korea
e-mail: yeona@dankook.ac.kr

B. Zhang et al. (eds.), *International Conference on Science Education 2012 Proceedings: Science Education: Policies and Social Responsibilities*,
DOI 10.1007/978-3-642-54365-4_7,

Students who have the different views of nature from the curriculum experience conflicts in science class (Won and Paik 2003). Students learn how nature works from science class. However, they learn nature with different meanings and objects in other subjects. Science educators need to pay attention to how other subjects perceive nature and what they teach about nature in order to have students form or explain the view of nature which science curriculum asks.

Today, students are learning science with a western view of nature. There are difference of views of nature between students and science education. Although students unwittingly systematize their experience of natural phenomena in accordance with their worldview, very few science educators realize this difference in students' cognition (Kawasaki 2007). It is necessary to understand Korean view of nature to make students form personal meaning about nature and process of conceptual change. In Korea, as in Japan, as students reach more advanced levels of science, they dislike science (Ohasi 2003). The reason is that science is separated from students' real world which is different from ideal and analytic world of science. Korea has a long history, enriched in culture and natural environment. It has its own view of nature. However, it is difficult to find a study about Koreans' view of nature in science education. The purpose of this study is to inquire Koreans' view of nature.

7.2 The Method of Study

In this study, Koreans' view of nature was analyzed by researching the written materials in Korean historical science, classical literature, and traditional folklore. Various kinds of written materials were used. Koreans' view of nature was analyzed by investigating written and oral folk myths, folktales, proverbs, history and scientific history, literature and arts, and papers that analyze these materials.

7.3 Results of the Study

The view of nature is formed under the influence of natural environment and the surrounding society. Korea's unique natural environment and industry, along with the influence of neighboring cultures, have affected Koreans' view of nature.

7.3.1 Meaning of Nature

In the west, nature is an objective substance. It's material object apposing to subjectivity. In science education, "nature" is a concept which is founded on the mechanical viewpoint. The meaning of "nature" in East Asia is different from that of the western area. "Jayeon" literally means "self-conscious," "my natural self," and "my conscience" (Kawasaki 1996). It's not substantive but adjectival. Koreans have considered "Jayeon" as something supernatural that gives an assurance of individual's virtue.

7.3.2 Conforming to Nature

The Korean Peninsula is a mountainous terrain; 70 % of the country is a mountain region. The sea is on three sides. Winter is cold and dry. There are rapid and severe changes in the natural environment during winter. For example, the riverbeds rise higher than the neighboring plains, torrential downpours, narrow woods, dry fall, and so on. Summer is very hot and humid so microorganisms become active. Typhoons come during the dry season in fall. It is rough and difficult to predict the weather on the sea. It is impossible to control them with human efforts. Koreans could not but conform themselves to nature.

Koreans believe in the God of Mountain and practice the worship of mountains. There are lots of eponymous stories in Korea. One of the common features of the stories is becoming a son of God in the mountain or forests (Kim 2005). This differs from stories that originate from Japan which are premised on the sea (No 2010).

Koreans feel in awe of nature. They think of nature as a parental presence. Koreans may express "…enter into the mountain" instead of "…climb up the mountain." Mountains are a part of nature. Its existence embraces everything as a parent, not an existence that should be climbed and conquered. They would refer to nature using honorific expression. The Korean expression "honorable rain is coming" is an example.

Nature is a teacher. It is believed that nature teaches good or ill luck to humans in order to prepare them (Park 2005). It enlightens them to greet it as if it's human therefore allowing nature to be observed carefully with the mind of love (Choi 2001).

7.3.3 Cyclical and Organic View of Nature

Koreans consider nature cyclical and recognize it as an organism (Lee 2002; Shin 2008). They follow natural rhythms and the life of grains and have a cyclical idea of time compared to Westerners' linear idea of time (Kim 2000). In this line of thinking, nature is alive and exists eternally with divinity. Humans enter into an interdependent connection with nature as an existence that has to adapt itself to cosmic principles. This cyclical and organic view of nature gave Koreans the idea that everything is a part of it. They try to settle for nature since the movement of nature is the criterion of living (Chung 1997). It's highly criticized to go against the providence of nature. Humans have to live according to natural flow. Stories or sayings in which those who challenge nature, such as "beating a rock with anger" or the effort to obtain the elixir of life, are about the contrary laws of nature.

Nature is a part of life. Nature is personified and becomes an autonomous existence. The ceremonies of the heavenly gods, goddess of the land, mountain gods, and exorcism are the examples of personification. Human beings are equated with nature. They have horizontal relationship with each other. In Korea, humans don't reign over animals, and animals don't harm humans. In shamanists' Chasa-bonpuri, the story of Bari princess shows horizontal relationship of equipoise between humans and animals rather than vertical master-servant relationship (Kim 2000).

Feng shui theory shows another example of the idea that the human is a part of nature. Feng shui theory is a thought to absorb a good Ki which is inherent in nature. Burying in the ground is a ceremony to unify nature. With the idea that mountain, water, and ground have life, it is a representation of intention to be in complete oneness with nature by harmonizing human to life (Kim et al. 1996; Kim 1987). According to feng shui theory, there are hundreds of different shapes depending on the terrain. They didn't change the layout of the land nor make a road to maintain the appearance (Choi 2001).

7.3.4 Pantheism and Monotheism

By the effect of agrarian society and the rapid natural change, pantheism and monotheism appear simultaneously. God of heaven is the concept of the one and only God. King of the other world and dragon kings rule their own territory. Other gods and spirits have their own role.

Active nature which is changed rapidly and severely had a big impact on Koreans' pantheistic view (Lee 2007). It is thought that numerous gods rule the natural phenomena, which humans cannot control. Pantheism caused naturalistic attitude toward human beings (Kim 2003). The sayings like "bad luck" ("jaesu"), "no fortune" ("un"), "heaven is indifferent," "sincerity moves heaven," and so on are used until now in daily life. That means that Koreans understand the world with pantheism before awareness. They still choose a lucky day, consult a fortuneteller, and predict marital harmony.

For Koreans, nature involves the cosmos. Nature and the cosmos are the same, goblins and spirits live with humans, and gods are kept in a shrine near humans (Chung 1997). Even in science textbooks used at schools in the end of Choseon dynasty, the existence of spirits were accepted (Park 2007). Different from monotheism, which consisted of class and order, spirits exist everywhere and everything keeps the horizontal relationship in the pantheism (Kim 2000; Hyun 1992):

> … After talking like that, the couple had a happy married life for a long time. Then, Hwangwooyang became the god of home, and his wife became the goddess of earth. The god of home is a guardian of it, and the head spirit of houses – spirit of kitchen, door, toilet,

goddess of birth and so on. The goddess of earth looks after the entire house, and protects the family who live in the house from misfortune. When the god of home felt negatively, the goddess of earth helped him, and the god of home assisted the goddess of earth. That's why we have no problems domestically… (The story of Hwangwooyang)

There are lots of gods and spirits in a home. They complement each other and maintain the peace of the home.

However, Koreans' pantheism is rather weaker than that of the Japanese who live in more severe natural phenomena like deeper valley, mountainous area, earthquakes, and frequent typhoon (Kim 1987).

7.3.5 Naturalness

Though the common point of Koreans, Chinese, and Japanese is pursuing the harmony with nature, there are differences. China had to fight against nature because of its broadness and width, sometimes wildness. So, China got to have an attitude of fighting nature. The beauty of nature for the Chinese means beauty of symmetry and balance. Mountains and valleys in Japan are deeper than in Korea. It is said that nature in Japan is like a flower garden in a box (Fuzisima 2003). The beauty seen in architecture and gardening in Japan represents the height of technique refined artificially.

On the contrary, Koreans try to reproduce the beauty in the natural form without artificiality (Kim and Kim 1998). Naturalness is Koreans' unique view of nature. They enjoy nature itself and do not try to change it (Lee 2007; Jin 1998).

7.3.6 Easy Integration with Strange Cultures

Koreans have a tendency to easily integrate with strange cultures. Mountains in Korea are not as high compared to those of Japan, and there's no isolated region in Korea. Since comings and goings were possible everywhere, they could accept others without rejection (An 1922; Kim 1987).

7.3.7 Evolutionary View

Koreans' view of nature was analyzed with stories. Mythologies are a better way to get ideas about view of nature than other kinds of stories. Koreans have lots of mythology resources, which can be classified into two categories: one is written resources and the other is oral. Resources from written literature are mostly the birth myths of the kings. They were written officially by historiographers and differ from the general public's perceptions.

Oral mythology is handed down as the shamanists' myths. From shamanists' myths, it is possible to get the idea of Koreans' view of nature. The view of nature from shamanists' myths can be summarized as follows: creation by yin and yang, worldview, and the creation and evolutionary view of nature.

Shaman mythology is richer than the written one. It is possible to see the evolutionary view of nature from the Song of Creation and Exorcism. Below is an excerpt of the shamanist myth, Song of Creation by Kim, a shaman.

Once upon a time, Buddha prayed to heaven holding a silver tray in one hand and golden tray in the other. Then five worms fell down on the golden tray and five on the silver tray. The worms grew up, and the golden ones became men and silver ones women. Finally, they married and people were made.

In this story, life was born by its own ability and the origin of human is heavenly. It's possible to find an evolutionary view about the creation of human being. It is also possible to see the idea of gender equality. Male and female are yin and yang; they exist harmoniously (Im 1998). The world is a representation of the efforts of heaven (Kim 1925). Both this world and the other world are good (Seo 2010), and the harmony of yin and yang is important as the myth of King Kim Suro (Son 2004). The harmony of yin and yang is represented by the idea of gender equality. The Song of Creation, the story about the stone of faithful wife, and lots of other stories show ideas that male and female respect each other and that there's no order of hierarchy. In those stories and the myth of Sirumal, the world was created in due order and gradually (Kim 1994, 2000).

7.3.8 Nature-Centered Creation

According to literary studies of Korea, written materials about the creation of the world are not easy to find. Written literature is often the founding myths, among which it is possible to see the creation of the world "Kyuwonsahwa jopangi." It is said to be the only written literature about creation of the world. In this story, it is possible to see the idea of ancient chaos and the god of cosmos. Humanity is an existence which is included in nature. The myth says:

> In the beginning, there were ancient chaos and god of cosmos. The god, called 'Hwan-In', divided heaven and earth and corrected the heavenly orbits right. 'Hwan' means a bright light representing the fundamental basis with the shape. 'In' means the cause. The god corrected the order of the world, sprang up all things, and created human being…Hwan-Ung, the son of emperor of heaven came down to the earth and ruled it by law of heaven…

It is possible to find Koreans' interest in origin from shamanists' myths (Shin 2004). It's difficult to find the efforts to dominate or change nature. Instead, nature-centered idea of creation appears. Nature exists independently and by its own ability (Hyun 1992). This idea is found in the myths of both inland region and Jeju Island. Heaven and earth were not created by the intention of the creator, but appeared naturally, thanks to the life and order in the beginning (No 2010; Jo 2003).

The following is a excerpt from the speech of Exorcism by Kang, a shaman:

> How did humans emerge after the creation of the world? He (a god) went to Amnok Mountain, gathered yellow soil and made man and woman. They, who were made with the soil, created everything while alive. After death, they went back to the ground, and became soil again.

In this story, humans are born in the soil and return to the earth, which shows nature-centered worldview and gender equality.

7.3.9 Utopia

For Koreans, nature plays a role of refuge from the tough reality (Choi 2002). Nature is a utopia and acts as a stage of Taoistic ramble. Since the Three Kingdom Period (57 B.C.–668 A.D.), nature was a tool which expressed the virtue of human beings. People have depended on nature whenever foreign country invaded or there were political difficulties.

7.4 Suggestions

With relation to this study, several things are suggested. Until now, in science classrooms, Koreans' traditional view and students' view of nature have not been considered. First of all, it is needed to understand students' beliefs and view of nature. Students have a mixed view of nature that incorporates the influence of western culture, religion, Korean cultures of family and society, and school science education. Many students have conflicted or mixed views about religion, scientific knowledge, and traditional culture. In order to make students construct correct scientific concepts, it is necessary to understand the view of Korean society and students' individual views of nature.

And then it is required to recompose the science curriculum, textbooks, and teaching-learning strategies to reflect Koreans' view of nature. There have been lots of attempts to adopt the history and achievements of Korean science. However, these attempts have only melded the contents of Korean science in the context of western modern science.

Second, it is necessary to develop teaching-learning strategies that consider different views of nature among students. Students learn various subjects at school. The view of nature in science education is different from the views of nature in other subjects. Koreans' traditional view of nature is emphasized more than the scientific view in Korea's mother tongue, art, ethics, and social science education. Teaching-learning strategies should be developed for students in order to prevent confusion.

Third, as Won and Paik's (2003) research noted, further study about the teachers' view of nature is also needed. Not only do students have mixed views about nature, but teachers do as well. Most elementary school science teachers in Korea did not major in science education, and they have conflicts between their own view of nature and scientific knowledge.

It's difficult to agree and accept scientific knowledge which is out of accord with one's view of nature. It is true that there are many students who just get scientific knowledge without agreement with their own beliefs or viewpoint and science educators who are not interested in problems related to views of nature. Science education considering views of nature will help students to have the right understanding of scientific knowledge.

References

An, J. (1922). *Ethnicity of Korean*. Seoul: Hanilbooks.

Choi, R. (2001). Korean's view of nature expressed in the words of popular religion. *Journal of Asian Comparative Folklore, 21*, 39–84.

Choi, T. (2002). View of nature in Korean classical literature. *Study of Korean Literature Criticism, 11*, 255–268.

Chung, J. (1997). *The aspect of moral culture structure in Korean traditional society*. Seoul: Korea University Press.

Cobern, W. W. (1991). *World view theory and science education research* (NARST Monograph No. 3). Manhattan: National Association for Research in Science Teaching.

Fuzisima, H. (2003). *Why do Japanese choose not 'science' but 'natural science'?* Tokyo: Tsukizi shokan.

Hyun, Y. (1992). *Mythology in shamanism and literature*. Seoul: Jipmoondang.

Im, J. (1998). Koreans' evolutionary view of nature from ancient mythology. *Study of Folklore, 8*, 243–277.

Jin, G. (1998). Koreans' view of nature from traditional cultural life. *Study on Philosophy and Phenomenology, 10*, 205–230.

Jo, H. (2003). Human and nature in Korean creation myth. *Research on Korean Language and Literature, 41*, 255–269.

Kawasaki, K. (1996). The concepts of science in Japanese and western education. *Science & Education, 5*, 1–20.

Kawasaki, K. (2007). Towards worldview education beyond language-culture incommensurability. *International Journal of Science and Mathematics Education, 5*, 29–48.

Kim, G. (1925). Superiority of Korean people. In S. Lee, K. Choi, J. Son, S. Lee (Eds.), (2011). *Birth of modern Korean*. Seoul: Somyong Publishing.

Kim, Y. (1987). Koreans' view of nature and science in Sejong period. *Study of Sejong, 2*, 55–79.

Kim, H. (1994). *Korean birth myth*. Seoul: Gilbeot.

Kim, W. (2000). *Green culture in Korea*. Seoul: Moonye Publishing.

Kim, I. (2003). *A study on the cultural foundations of Korean education: Attaching importance to Korean Shamanism*. Paju: Korean Studies Information.

Kim, K. (2005). Korean's traditional perception of nature – With a special focus on Korean geomancy. *Journal of the Study of Korean History of Thoughts, 23*, 1–25.

Kim, Y., & Kim, Y. (1998). *Oriental science and thoughts*. Seoul: Iljisa.

Kim, S., Kim, Y., Kim, U., Nam, K., Shin, W., Jang, J., Chung, S., Pyun, M., & Hwang, P. (1996). *Thoughts of Korean folklore*. Seoul: Jipmoondang.

Lee, Y. (2002). A conceptual review of the Korean worldview for the development of nursing theory. *Journal of Nursing for Adult, 14*(4), 612–624.

Lee, G. (2007). *Koreans' mindset 3*. Seoul: Shinwon Book.

No, S. (2010). *A comparative study on Korean and Japanese mythology*. Seoul: Minsokwon.

Ohashi, Y. (2003). The Japanese concept of science. Annual report of the faculty of education, *37*, 1–14. Bunkyo University Faculty of Education.

Park, S. (2005). *Korean history of science*. Seoul: Youth Book.

Park, J. (2007). *Science textbook in the end of Choseon dynasty*. Paju: Korean Studies Information.

Seo, J. (2010). *Myth, we should know*. Seoul: Hyeonamsa.

Shin, D. (2004). A study on the traditional view of nature. *Study of Modern Literary Theory, 23*, 7–26.

Shin, J. (2008). The dialectic of discourse of shamanism in colonization period and literature. *SAI, 4*, 361–391.

Son, J. (2004). *Korean myth reading again*. Seoul: Human & Books.

Won, J., & Paik, S. (2003). Elementary school students' views about nature. *Journal of the Korean Association for Research in Science Education, 23*(1), 9–20.

Part III
Science Teacher Education

Chapter 8
New Curriculum Structure of High School in China

Boqin Liao, Juan Yang, and Yannan Shao

Abstract This paper introduces the new curriculum structure of high school in the new round curriculum reform in China. There are eight learning areas in the new curriculum structure: language and literature, math, humanities and society, sciences, technology, arts, physical education and health, and comprehensive practice activities. The science learning areas include three subjects: physics, chemistry, and biology. The new physics curriculum structure is presented as a special sample of the new curriculum structure, and it is composed of two parts, required courses and optional courses, which include 12 modules. Based on a series of comparison and analysis on different international curriculum structures, the similarities of them emphasize the curriculum foundation, diversity, and selectivity, and the differences lie in the designs of curriculum structures. In China, the new physics curriculum structure has three tiers, and each tier has several levels integrating the modules' characteristics, which indicate that the new physics curriculum structure of high school mainly focuses on the students' all-around and individual development.

Keywords Curriculum reform • High school • Curriculum structure

Since 1999 China has carried out the new curriculum reform for basic education. During this round curriculum reform curriculum standards textbooks teaching methods and evaluation for each subject have been systematically reformed. This paper focuses on the new structure for high schools in this round curriculum reform

B. Liao (✉) • J. Yang
The Research Center of Science Education, Southwest University, Chongqing 400715, China
e-mail: bqliao@swu.edu.cn; yang223588@126.com

Y. Shao
College of Education, Capital Normal University, Beijing, China
e-mail: yannan@swu.edu.cn

B. Zhang et al. (eds.), *International Conference on Science Education 2012 Proceedings: Science Education: Policies and Social Responsibilities*,
DOI 10.1007/978-3-642-54365-4_8,

8.1 Introduction

China embarks on a basic educational curriculum reform at the beginning of the twenty-first century, including curriculum reform in compulsory education and upper secondary education. The form involved six aspects including curricular contents, teaching methods, curriculum evaluation, and curriculum management. This paper mainly focuses on the new curriculum structure in China.

In the new round of curriculum reform for basic education, the documentation Curriculum Standards for the Subject of Physics in High Schools has been issued in April 2003, and it has been piloted as test documentation in practice (Ministry of Education of the People's Republic of China [MEPRC] 2003a, b). We introduce the new physics curriculum structure for the high schools first and then discuss understanding of new structure for the new curriculum.

8.2 Learning Area: New Structure for the New Curriculum

According to international comparison, all the high school curricula in different countries emphasize on the foundation and selectivity, especially the curriculum selectivity that benefits individual development (Tan Fei and Yang Liu 2011).

The reformed new curriculum for the high schools contains three levels, learning areas, the subjects, and modules, making an attempt to highlight the features of varieties and selectivity, aiming at constructing the basic and flexible structures for each course. Table 8.1 shows the learning areas on language and literature, math, humanities and society, sciences, technology, arts, physical education and health, and comprehensive practice activities in senior middle schools. Every learning area includes several subjects, and each subject contains several modules; thus, a module is the most basic unit for the content of the subjects.

The establishment of the learning area can reflect the integration of the modern sciences and help to set up the subjects, design the standard for each subject, and guide teachers' teaching. This helps design course content, improves students' performance, and ensures all-around student development. Meanwhile, the establishment of the learning area can make students get credits in all learning areas each semester, which prevents students from getting bored on one or some subjects and reduces the overlap of the subjects' content.

The learning area is constructed by some curricula that have similar values. The learning area covers the following subjects: Chinese, math, foreign languages, (including English, Japanese, and Russia), moral education, history, geography, physics, chemistry, biology, arts (either music or fine art), PE and health, and information technology and applied technology. The standards of each subject are covered by the learning areas, and credits have been required at national level to ensure that all students are standing on the same basis.

Table 8.1 Course structure for high schools

Learning area	Subjects (required credits)	Modules
Language and literature	Chinese (10)	Required: Chinese 1, Chinese 2, Chinese 3, Chinese 4, Chinese 5, (reading and perception, expression and communication)
		Optional: poetry and essays, novels and plays, news and biography, application of language, literature readings
	Foreign language (10)	Required: English 1, English 2, English 3, English 4, English 5
		Optional: courses in sequence (six modules), language knowledge and skills, application of language, appreciatory courses (three modules)
Math	Math (10)	Required: Math 1, Math 2, Math 3, Math 4, Math 5
		Optional: Series 1 (two modules), Series 2 (three modules), Series 3 (six modules), Series 4 (ten modules)
Humanities and society	Politics (8)	
	History (6)	Required: History 1, History 2, History 3
		Optional: reforms in history, democracy and its practice in modern society, war and peace in twentieth century; big guys in history; exploring the mystery in history; world legacies
	Geography (6)	Required: Geography 1, Geography 2, Geography 3
		Optional: space and earth, ocean geography, traveling geography, city-town planning, national calamity and its prevention, environmental protection, geographic information technology
Science	Physics (6)	Required: Physics 1, Physics 2
		Optional: Series 1 (two modules), Series 2 (three modules), Series 3 (five modules)
	Chemistry (6)	Required: Chemistry 1, Chemistry 2
		Optional: chemistry and daily life, chemistry and technology, material structure and nature, principles of chemical reactions, organic chemistry, experimental chemistry
	Biology (6)	Required: Biology 1 (molecule and cell), Biology 2 (genetics and evolution), Biology 3 (stable state and environment)
		Optional: Optional 1 (the application of biological technology), Optional 2 (biological science and the society), Optional 3 (biological technologies in contemporary times)

(continued)

Table 8.1 (continued)

Learning area	Subjects (required credits)	Modules
Technology	Commonly used technologies (4)	Required: Technology and Design 1, Technology and Design 2 Optional: electronic control, robot-making, the modern technologies for agriculture, domestic science and technology, car drivers and maintenance, architecture and design, clothes and design
	Information technology (4)	Required: foundations to information technology Optional: algorithm and programming, the applications of multimedia, the applications of web-based technology, data management system, artificial intelligence
PE and health	PE and health (11)	Series 1, balls; Series 2, gymnastics; Series 3, tracks; Series 4, sports on water and ice; Series 5, folk's sports; Series 6, newly developing sports; Series 7, health education
Arts	Fine art (3)	Appreciation of fine art, drawing and sculpture, design and craft, calligraphy and carve, arts of modern media
	Music (3)	Appreciation of music, singing, performance, composition, music and dance, music and drama
	Art (6)	Art and daily life, art and emotions, art and cultures, art and sciences
Comprehensive practice activities	Investigative study (15), community services (2), social practices (6)	

Each subject consists of several modules. Each module has its own separated structure, which constructs a learning unit; the modules are related in logic. Each module has its own educational goals and centers around a certain content (Department of Basic Education and Department of Normal Schools of Ministry of Education 2004).

8.3 Sample: New Structure for Physics in High Schools

As for the physics curriculum, the curriculum structure design is based on analysis of the document, The High School Physics Teaching Syllabus in China, with a large number of questionnaire investigations, empirical study, and international comparative study (MEPRC 2002; Liao Boqin et al. 2002).

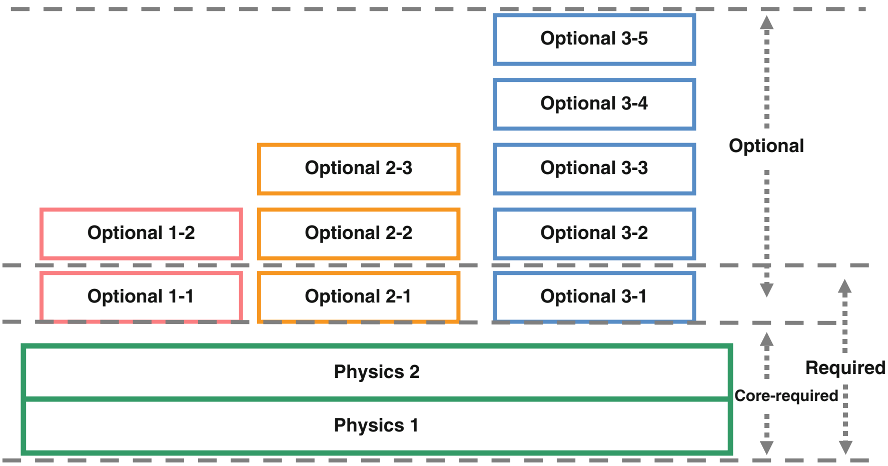


Fig. 8.1 The structure of physics in high schools

From above, we have known the new structure of the new curriculum in Chinese high schools, and each subject has different structures constituted by different modules. We take physics as example to elaborate the structure of the subject.

Physics in the new curriculum is composed of two parts, required courses and optional courses, in the attempt to emphasize the foundation and selection in the course design, which include 12 modules: Physics 1 and Physics 2; Optional 1-1 and Optional 1-2; Optional 2-1, Optional 2-2, and Optional 2-3; Optional 3-1, Optional 3-2, Optional 3-3, Optional 3-4, and Optional 3-5. Among them, Physics 1 and Physics 2 are the core modules and are required. Other modules are optional. Each module has two credits. Students receive four credits after they finish the required modules; in order to get the six required credits, students must take one module related to Physics 1 and Physics 2; therefore, students can only choose among Optional 1-1, Optional 2-1, and Optional 3-1, because these three modules are related to electromagnetics.

After students take six credits, they may take several optional modules to finish the required credits in the learning area of sciences according to their interests, their potential development, and their careers in the future. These optional modules make the path for students to study further.

Figure 8.1 shows the structure of physics in high schools (MEPRC 2003a, b):

Some further comments on physics in the new curriculum:

1. Core-required Physics 1 and Physics 2 are designed for all the high school students. Students have experience on the characteristics and methods employed in physics through studying on the core contents and experiments such as principles of the object locomotion, inter-effect, power, and so on, at the same time. Students construct acknowledge on their interests and their potential development and prepare for the further study.

2. The selectivity of physics has been reflected not only by the credits of the optional courses but also by the required credits. Students get four credits after finishing the core-required course, then, students may get two more credits by taking Optional 1-1, Optional 2-1, or Optional 3-1.
3. After the completion of the required credits, students may choose the related contents as further study in accordance with their interests, their potential development, and the demands for the careers in the future. Teachers may guide students to choose the follow-up courses sequentially in reference with the figure "the structure of physics in high schools." It is acceptable if students make the leap in the choice of the optional courses based on their own situations.

8.4 Samples for Module Integration

The integration of modules may ensure individual's development. In the new curriculum, a module is the smallest unit constructing the course structure; however each module has a comprehensive educational function, and the series in each module emphasize the different sides of the educational function. We take the module samples in physics to deliberate the educational function by the integration of modules.

In the course structure of physics, each module has the conceptions, principles, experiments, physical thoughts, physical methods, the relationship of physics and social development, the relationship of physics and application on technology, the relationship of physics and daily life, and so on.

Physics 1 and Physics 2 are the core-required modules for all students. Students will learn the contents such as "describing motion," "force and motion laws," "mechanical energy and energy source," "projectile motion and circular motion," and "achievement and limits of classical mechanisms." By studying these contents, students experience the scientific exploration and have the elementary knowledge on the characteristics of physics and its methods and experience the effects of physics on daily life, industrial production, and society. Students may make the preparations for the follow-up studies. These two core-required modules stress the scientific exploration and the physical experiments, highlight the physical methods and thoughts, emphasize the inter-effect between physics and society, and pay attention to the integration of classical physics and modern physics.

Optional 1-1 and Optional 1-2 are called Optional Series 1, totally four credits. The modules in this series mainly focus on the key concepts of electromagnetics and calorifics, emphasize the relationship and the inter-effect between physics and society, highlight on the aspect of humanities in physics, pay attention to the integration of physics and daily life and social science and humanities, and stress the influence of physics on the civilization. Students will learn the "phenomena and principles of electromagnetics," "technique of electromagnetics and social development," and "daily electronic utilities and daily life" in Optional 1-1; students will learn the "phenomena and principles of calorifics," "calorifics and daily life," and "energy source and social development" in Optional 1-2.

Optional 2-1, Optional 2-2, and Optional 2-3 are called Optional Series 2, totally six credits. The modules in this series reveal physics from the perspective of the application, put the emphasis on the collaboration of physics and technology, and mainly focus on the application and practical use of physics. Students will learn about “electro circuit and electricity” and “electromagnetic wave and information technology” in Optional 2-1; students will learn about “force and machine” and “heat and energetic machines” in Optional 2-2; in Optional 2-3, “light and optical instrument” and “atom structure and nuclear technology” will be learned.

Optional Series 3 contains Optional 3-1, Optional 3-2, Optional 3-3, Optional 3-4, and Optional 3-5, totally ten credits. The modules in this series stress the fundamental knowledge in physics, provide knowledge on physical thoughts and methodology, and make students aware of the application of physics and its influence on the economy and the society. Students will learn about “electric field,” “electric circuit,” and “magnetic field” in Optional 3-1; in Optional 3-2, “electromagnetic induction,” “alternating current,” and “sensors” are mainly contained; in Optional 3-3, “theory of molecule motion and thought of statistics”; “solid, liquid, and gas”; “thermodynamic laws and conversation of energy”; and “energy sources and sustainable development” will be learned; in Optional 3-4, “mechanical vibration,” “electromagnetic shake and electromagnetic wave,” “light,” and “the relativity” will be put forward to; in Optional 3-5, students will learn “collision and momentum conservation,” “atomic structure,” “nucleus,” and “the dual nature of both wave and particles.”

8.5 Comparison of the Science Curriculum Structure in China to Those of Other Countries

The science curriculum structures of America, Finland, Ontario in Canada, and South Korea are selected for comparison (NCES 2007; The Ministry of Ontario Education 2008a, b; The Ministry of Education Republic of Korea 2007). The comparison results indicate similarities and differences of different countries’ science curriculum structures. The similarities are that all of them emphasize the curriculum foundation, diversity, and selectivity, and the differences are the designs of curriculum structure, as the new physics curriculum structure in China has three tiers and each tier has several levels integrating the modules’ characteristic. The three tiers indicate the new physics structure of high school in China, which underscores the students’ all-around and individual development.

8.6 Conclusions

The new curriculum of high schools in China that builds on the 9-year compulsory education stresses the improvement of the national citizen’s quality of life, the fundamental education for all people, and the foundation to students’ lifelong study.

At the guidance of the ideas and the principles of the student-based development, the new curriculum underscores the fundamental contents for students' lifelong study and constructs the relations of the social development, science advancement, and students' experiences; thus, the new curriculum constructs the fundamental, diversified, multileveled, and comprehensive course structure, which aims at meeting the demands of the society and students' individual development in all rounds.

Acknowledgment The authors would like to thank the Southwest Nationalities' Traditional Technology of Modern Education Transformational Research Funding from the Ministry of Education in China in 2011 (Grant No. 11JJD880017) and the Science Education Research Funding from Chongqing Humanities and Social Sciences Research Base in China (Grant No. 11SKB11) for their supports in this research.

References

Department of Basic Education & Department of Normal Schools, Ministry of Education. (2004). *Research manual for the new curriculum for high schools: Curriculum schemes-formation and guidance for students' selection*. Beijing: Higher Education Press.

Liao Boqin, Zhang Dachang, Li Yuanrong. (2002). *The research report of high school physics curriculum international comparison*. Submitted to the Ministry of Education of the People's Republic of China.

Ministry of Education of the People's Republic of China. (2002). The high school physics teaching syllabus in China. http://www.moe.gov.cn/publicfiles/business/htmlfiles/moe/moe_25/200204/237.html. Accessed 12 Dec 2012.

Ministry of Education of the People's Republic of China. (2003a). Curriculum reform program for regular high school (experiment). http://www.moe.gov.cn/publicfiles/business/htmlfiles/moe/moe_711/201001/78378.html. Accessed 25 Oct 2012.

Ministry of Education of the People's Republic of China. (2003b). *Standards for the subject of physics in high schools (experiment)*. Beijing: People's Education Publishing House.

NCES. (2007). Secondary school course classification system: School codes for the exchange of data (SCED). http://nces.ed.gov/pubs2007/2007341.pdf. Accessed 12 Dec 2012.

Tan Fei, & Yang Liu. (2011). Review of 2009 school curriculum reform policy in Korea. *Comparative Education Review, 5*, 15–19.

The Ministry of Education Republic of Korea. (2007). Secondary education. http://english.moe.go.kr/web/1696/site/contents/en/en_0206.jsp. Accessed 12 Apr 2014.

The Ministry of Ontario Education. (2008a). *The Ontario curriculum grades 9 and 10 sciences*. Ontario: Queen's Printer for Ontario.

The Ministry of Ontario Education. (2008b). *The Ontario curriculum grades 11 and 12 sciences*. Ontario: Queen's Printer for Ontario.

Chapter 9
An Experimental Study on the Integrated Mode of the Computer Simulation in Scientific Discovery Learning in Middle School Physics Education

Taihua Li, Lingmin Yuan, Qinling Wang, and Boqin Liao

Abstract Computer simulation can offer an open exploring learning environment for students. Therefore, it is usually considered as an instrument for the scientific discovery learning. Based upon the recent research, we analyzed the components of scientific discovery learning. Moreover, according to the teaching experience and the earlier investigations, we took computer simulation as an exploring tool for middle school students' scientific discovery learning in their physics education. We designed an integrated mode, which could integrate computer simulation into experiments in the laboratory. Compared to the scientific discovery learning mode that is based upon the real-life experience, the results of the experimental study were as follows: (1) the integrated mode of computer simulation in scientific discovery learning showed very significant improved effects upon the students' mastery of the principle knowledge; (2) the integrated mode of computer simulation in scientific discovery learning showed no significant improved effects upon the students' intuitional understanding; (3) the integrated model of computer simulation into scientific discovery learning showed significant improved effects upon the students' mastery of the flexible application of the knowledge; (4) the students' achievement of physics had very significant effects upon their scientific discovery learning; (5) the integrated mode could make better use of the advantages of both the

This paper was funded by the project of the Key Research Institute of Humanities and Social Sciences at University of Chongqing.

T. Li (✉) • B. Liao
The Research Center of Science Education, Southwest University, Chongqing 400715, China
e-mail: litaihua@gmail.com; bqliao@swu.edu.cn

L. Yuan
School of Physics and Electronic Engineering, Sichuan Normal University,
Chengdu 610100, China
e-mail: yuanlingmin2007@163.com

Q. Wang
College of International Studies, Southwest University, Chongqing 400715, China
e-mail: wangqinling@gmail.com

B. Zhang et al. (eds.), *International Conference on Science Education 2012 Proceedings: Science Education: Policies and Social Responsibilities*,
DOI 10.1007/978-3-642-54365-4_9,

computer-simulated situations and the real-life experience, while at the same time it has some limitations in students' understanding of the nature of the experiments and in testers' grasping of the variations of students' naive conceptions.

Keywords Computer simulation • Scientific discovery learning • Integrated mode • Middle school physics education

9.1 Introduction

Recently, with the rapid development of Chinese education, modern teaching multimedia with the computer as its core is becoming more popular, and this has greatly enhanced the reform of basic education. Especially in the field of middle school physics education, multimedia technology is being widely used. The multimedia has an integrated character: images, audio, cartoon, animation, video and interactivity have brought an "added value" for the physics education (Jerry Wellington 1999). With further development of the physics curriculum reform, there is an increasing emphasis on the inquiry learning, the core of which involves high-level thinking and knowledge constructing. Under the influence of the constructivist learning theory, scientific discovery learning as a way of inquiry learning has attracted a wider attention (von Joolingen and de Jong 1997).

On the other hand, an important trend of the integration of computer technology with education is that the comprehensive application of multimedia, network communication, and other new technologies is emphasized more to create an open, active scientific discovery learning environment for students' development of high-level thinking and problem solving (Chen and Liu 1997). On the basis of this background, a lot of studies on the application of computers to education show that computer simulation can be used to create an open inquiry learning environment for students to construct concepts and principles, to develop high levels of cognitive skills through their manipulation, and to explore computer-simulated situations (Jong and Njoo 1992). Thus computer simulation can construct learning tools so as to meet the students' needs of inquiry learning. Scientific discovery learning based on computer simulation as one form is catching more attention from researchers.

Most studies of scientific discovery learning based on computer simulation explore the teaching function of computer simulation from the perspective of the educational technology or educational psychology (Zhang Jianwei and Chen Qi 2001a) and less of them from the perspective of its application to specific subject teaching. Most of them focus on "how to improve the design of computer-simulated situation, and how to provide a good inquiry learning environment for scientific discovery learning" (Goodyear 1992), while less of them from the computer-simulated situation to explore reasonable positioning and the integrated mode of computer simulation on the condition of utilizing the components of scientific discovery learning.

Based on this background, after analyzing the components and the functions of computer simulation in scientific discovery learning, an integrated mode of computer simulation to scientific discovery learning in middle school physics education is designed. The effect of the computer simulation of the integrated mode on scientific discovery learning and its relevant factors are to be discovered below.

9.2 Exploring the Integrated Mode of Computer Simulation to Scientific Discovery Learning

9.2.1 Analyzing the Components of Scientific Discovery Learning

According to the studies of Jong and Njoo, Zhang, and Chen, the scientific discovery learning is a kind of self-directed learning, during which the learners' self-monitoring activity plays a very important role to ensure the successful carrying out of scientific discovery learning (De Jong and Njoo 1992). These studies show that scientific discovery learning consists of three basic components: learners' exploring activity, learners' self-monitoring activity, and learners' knowledge-constructing activity. The learner's existing knowledge plays an important role in the three activities.

The learners' physics knowledge is the background and starting point of their exploring activities, the precondition and basis of learners' self-monitoring and knowledge construction. The exploring activities of learners are an explicit form of scientific discovery learning, associated with activities of self-monitoring and knowledge constructing, which are an implicit form of scientific discovery learning. Learners' self-monitoring activities are necessary for posing problems and generating hypotheses, critical for successful experiment activity. The learner's knowledge-constructing activity, which is the main goal of scientific discovery learning, is based on the exploring activity and the self-monitoring activity. The interaction of learner's three basic activities and basic physics knowledge forms the basic components of scientific discovery learning (Fig. 9.1).

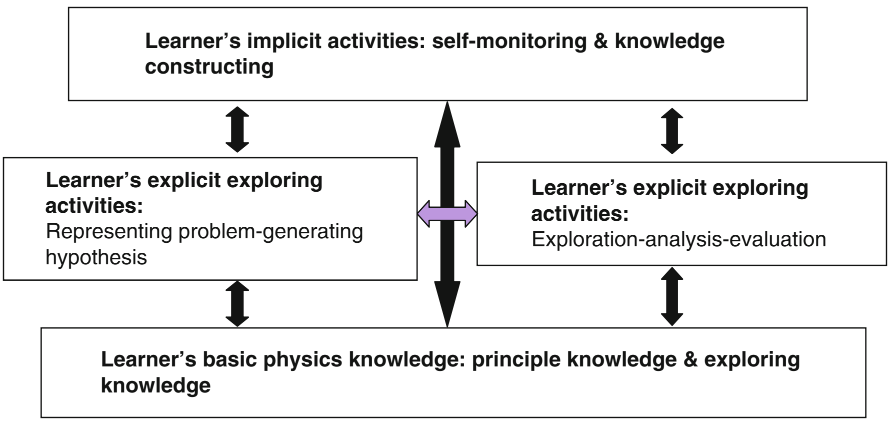


Fig. 9.1 The basic components of scientific discovery learning

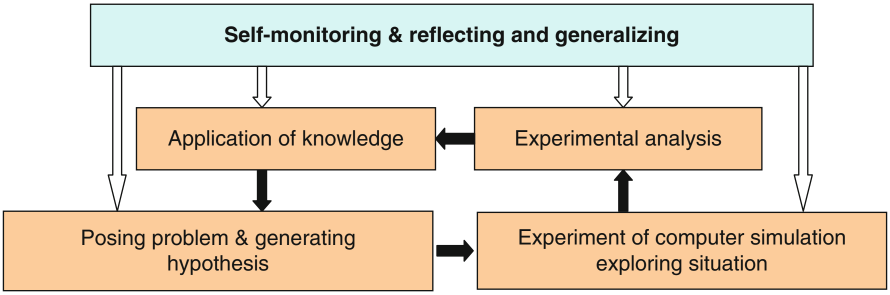


Fig. 9.2 The basic model of computer simulation in scientific discovery learning

9.2.2 Designing the Integrated Mode of Computer Simulation to Scientific Discovery Learning

On the basis of the previous analysis of the basic components of scientific discovery learning, the function of computer simulation in scientific discovery learning is oriented; the basis of scientific discovery learning is summarized; the basic mode of computer simulation in scientific discovery learning is designed (Fig. 9.2); and the experimental studies are carried on (Zhang Jianwei and Chen Qi 2001b; Li 2009).

It is found that computer simulation in scientific discovery learning makes students acquire knowledge more easily. The results have significant effect on the test of learners' intuitive understanding and flexible application. However, the in-depth analysis of students' scores and feedback shows that the basic mode of computer simulation in scientific discovery learning also has some limitations. How do these limitations happen? The analysis shows that there may be two reasons (Li 2009): Although the experiment could be carried step by step in the computer-simulated situation and with fewer trials and mistakes, students enjoyed themselves more with real-life exploration; however, with lack of real experience, they cannot accurately understand the knowledge and the experience that must be obtained from real life. There are lack of self-monitoring and knowledge constructing in the whole process of scientific discovery learning, lack of timely in-depth reflection and generalization in the stage of experimental analysis and the application of knowledge, and lack of recognition of the deficiency of the scientific nature of the findings.

On the basis of experimental studies of the basic mode, computer simulation to scientific discovery learning is improved; therefore, the integrated mode of computer simulation in scientific discovery learning is redesigned (Fig. 9.3), which is developed in the part of experimental exploration: the real experimental situation is integrated on the basis of the experimental exploration of the simulated situations. The aim is to strengthen the students' exploring, knowledge-constructing, and self-monitoring activities.

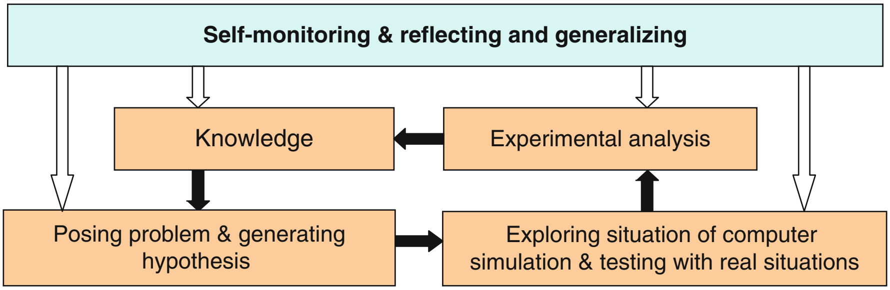


Fig. 9.3 The integrated mode of computer simulation in scientific discovery learning

9.3 Design

On the basis of the comparison of the mode in real situations and the mode of computer simulation in scientific discovery learning, the result of the integrated mode of computer simulation to scientific discovery learning is examined in the experiment. Through the analysis of the process of scientific discovery learning, the effects of computer simulation are discussed in regard to students' principle knowledge, intuitive understanding, and flexible application. This was to check the different effects of the different modes. On the basis of that, the experiment is carried out with quantitative and qualitative methods.

9.4 Experimental Process and Results

9.4.1 Methodology

9.4.1.1 Computer-Simulated Course Wares

In the experiment, the computer-simulated course wares "exploring the effect of gravity on speed" and "exploring the effect of friction on speed" were used (Fig. 9.4).

The scientific and teaching function of the simulated course wares has been examined and approved by the Physics Teaching Research Office in the Institute of Education Research in Chongqing; the technique of the course wares has been confirmed by experts of computer-assisted instruction in the Department of Educational Technology of Southwest University.

9.4.1.2 Sample

The students in high school affiliated to Southwest University are selected as the objects of the experiment. Two comparable classes in the school were selected: one

Fig. 9.4 The course wares of “exploring the effect of gravity on speed” and “exploring the effect of friction on speed”

experimental class and one control class. Their physics levels are tested before the experiment with the independent samples of t-test, and the results show no significant difference ($t = .624$, $P = .535 > .05$).

9.4.1.3 Design

The study is designed as one single factor with two levels. The single factor is the scientific discovery learning mode, while the two levels are the integrated mode of computer simulation in scientific discovery learning and the mode based on the real situations. The dependent variables are the students' principle knowledge, intuitive understanding, and flexible application.

9.4.1.4 Process

The experimental class and the control class are taught by Miss Chen (a 45-year-old high school teacher with an undergraduate degree). The testers design the teaching plan and take part in the whole process of teaching so as to ensure the scientific conducting of the experiment and to avoid the differences caused by the teacher. In addition, in order to ensure that the teacher can understand the experiment goal thoroughly, she is invited to participate in the design of the course wares and the experiment, the preparation of the test materials, and a number of discussions.

Before the experiment, the "mechanics" part has been taught. The students have done some exploring activities about kinematics, acoustics, and optics and have grasped some basic exploring knowledge.

The scientific discovery learning is carried on in the experimental class and the control class at the same time during December 18, 2009–January 3, 2010 (total of 17 days and 9 h for each class). The experimental procedure is as follows:

The experimental class: posing problem and generating hypothesis → experimental exploration with computer simulation → real experimental test → experimental analysis → application.

The control class: posing problem and generating hypothesis → experimental exploration1 → experimental exploration2 → experimental analysis → application (Li 2009).

There is a 60-min test after the experiment on January 3, 2010.

9.4.1.5 Test

- The students are tested from three aspects:
  1. Principle knowledge: to examine whether the students have found the law of convex imaging as well as their understanding and memorization.
  2. Intuitive understanding: considered as an important goal of scientific discovery learning, it is not to test the general principle knowledge, but to generate intuitive understanding and judgment in the specific situations, which reflects students' deep understanding.
  3. Flexible application: used to check students' flexible summarization and application of the findings of the new situations.

- Test materials:
  The experimental test materials are prepared by both the testers and the teacher. The test questions of principle knowledge are from previous junior high school graduation examination papers, while the questions of intuitive understanding are prepared on the basis of the relevant study of scientific discovery learning and are revised by the teacher. The questions of flexible application are adopted on the basis of some application problems from "the 8th grade physics experimental teaching materials for teachers" and "the textbook for students of grade two in junior high school in Chongqing." The test materials have been examined by the Physics Teaching Research Office in the Institute of Education Research in Chongqing and have been adopted in some other schools before the experiment. On the basis of the examination and experiment, the test materials are amended to ensure good reliability and validity.

9.4.2 Results

The posttest scores of experimental class and the control class are showed in Table 9.1. The modes are taken as between-subject factors, the scores of midterm physics examinations are taken as covariate, and the results of the analysis of variance of the test results of principle knowledge, intuitive understanding, and flexible application are showed in Table 9.2.

Table 9.2 shows that:

1. Principle knowledge: there is very significant difference of test scores between the two modes in the principle knowledge ($P = .007 < .01$); and there is very significant difference in the scores of the midterm physics examination as covariate ($P = .001 < .01$).
2. Intuitive understanding: there is no significant difference in the test scores between the two modes in the intuitive understanding ($P = .080 > .05$); and there is very significant difference in the scores of the midterm physics examination as covariate ($P = .000 < .01$).

   In order to analyze the effect of the differences of the test scores of the two modes on the principle knowledge, the students are divided into three groups according to their achievements (high score, scores of the midterm physics examination ≥80; medium score, 60≤ scores of the midterm physics examination <80; low score, scores of the midterm physics examination <60). Then the different modes are taken as between-subject factors, and the samples in the different groups of the two classes are tested with the independent samples of the *t*-test. It is found that there is significant difference of the test scores of the intuitive understanding between the two classes of the high-score group ($P = .043 < .05$); there is approximate significant difference of the test scores of the principle knowledge between the two classes of the medium score group ($.05 < P = .062 < .1$); but there is no significant difference of the test scores of the principle knowledge between the two classes of the low-score group ($P = .108 > .05$).

Table 9.1 The average and standard deviation of the posttest

Class	Principle knowledge		Intuitive understanding		Flexible application	
	M	SD	*M*	SD	*M*	SD
Experimental class	15.89	2.96	22.13	4.96	36.34	8.69
Control class	14.25	3.41	21.08	5.45	32.51	9.06

The results are processed with SPSS10.0

Table 9.2 The analysis of the covariance

Type of achievement	Source of difference	Sum of squares	df	Mean square	*F*	*P*
Principle knowledge	The mode	71.058	1	71.058	7.528	.007**
	Score of the midterm physics examination	107.008	1	107.008	11.337	.001**
Intuitive understanding	The mode	35.232	1	35.232	3.116	.080
	Score of the midterm physics examination	153.208	1	153.208	13.550	.000**
Flexible application	The mode	268.380	1	268.380	5.586	.020*
	Score of the midterm physics examination	3,957.088	1	3,957.088	82.363	.000**

*It is significant at the level of .05. **It is significant at the level of .01

3. Flexible application: the results of the analysis of variance show that there is significant difference of the scores between the two modes on the flexible application ($P = .020 < .05$); and there is very significant difference of the scores of the midterm physics examination as covariate ($P = .000 < .01$).

9.4.3 Analyses and Discussions

9.4.3.1 The Effects of the Integrated Mode of Computer Simulation in Scientific Discovery Learning on the Students' Principle Knowledge

In this experiment, the integrated mode of computer simulation in scientific discovering learning improves the students' mastery of principle knowledge better than the real-life mode. In the integrated mode, the computer-simulated situation of the core concept of "velocity" provides three levels of representations: dynamic phenomena, movement traces, and detailed exercise data. The dynamic phenomena enable students to obtain the visual perception of the approximate real situation;

the computer-simulated object motion traces further formalize “the changes of velocity of an object”; and the detailed exercise data make students acquire more accurate experience than the direct observation, which makes the students surpass the experience of the visual intuition to better judge the speed changes. Furthermore, in the integrated mode of computer simulation in scientific discovery learning, the students can change the experimental variables at their will. By observing the changes of the variables, they can generate hypotheses and find the relation between them better.

9.4.3.2 The Effects of the Integrated Mode of Computer Simulation in Scientific Discovery Learning on Students' Intuitive Understanding

In the experiment, there is no significant improvement of the integrated mode of computer situation in scientific discovery learning in the students' intuitive understanding. But through further analysis it is found that there is significant improvement of this integrated mode in the students' intuitive understanding in the high-score group, approximate significant improvement for the medium score group, and no significant improvement for the low-score group.

There are rich representations and convenient operations of the integrated mode of computer simulation in scientific discovery learning which provide a favorable environment and an adequate factual information to test all hypotheses. Students should have two basic skills to coordinate data with their previous knowledge through their experimental explorations. First, students should do some reflection on their previous knowledge so as to further understand them; second, students should have the ability to recognize the evidence which denies the hypotheses. Therefore, students with good achievements can take advantage of the integrated mode of computer simulation in scientific discovery learning so as to change their former naive understanding of the relevant physics knowledge.

9.4.3.3 The Effect of Integrated Mode of Computer Simulation in Scientific Discovery Learning on Students' Flexible Application

In the experiment, there is significant difference of test scores of students' flexible application between the integrated mode of computer simulation in scientific discovery learning and the real experience mode. Through the analysis of the integrated mode of computer simulation in scientific discovery learning, it is found that this mode has some advantages in improving the students' flexible application. The simulated situations of the integrated mode enable students to have an essential understanding of the causes of the velocity variation. The simulated situations of the integrated mode can afford different environments of gravity (such as Moon, Mars) for students. The real experiment of the integrated mode can enable students to find out the regularity which occurs in the simulated situations so as to establish the corresponding connections between the abstract laws in their physics learning and the specific situations in time.

9.4.3.4 Effect of Basic Physics Knowledge on Scientific Discovery Learning

In the experiment, there is a significant effect of students' basic physics knowledge on the test scores of the principle knowledge, intuitive understanding, and flexible application, which is in accordance with the studies of Joolingen and Jong and Zhang Jianwei. The results show that the students' basic physics knowledge plays an important role in their scientific discovery learning.

9.4.3.5 Limitations of the Integrated Mode of Computer Simulation in Scientific Discovery Learning

In the experiment of the basic mode, the information from the students shows some negative effects of the simple computer-simulated situation experiment, which is improved in the experiment of the integrated mode of computer simulation in scientific discovery learning. Through the analysis of this experimental study, it is found that the integrated mode can take advantage of the computer-simulated situation experiments and the real-life experiences.

At the same time, the analysis of the process and results of students' science discovery learning also shows that there are some limitations about the integrated model. Some students fail to recognize the essential differences between the real-life experiences and the computer-simulated experiments. Some students are confused about some conceptual changes. The computer-simulated situations can exclude some interfering factors of the real-life physics environment so as to find the implicit laws in the physics phenomena and to better improve the students' naive concepts. But through the real-life experiments, the students may only get naive concepts about the physics phenomena under the influence of the interfering factors of the real-life situations once again to reactivate the previous naive concepts.

Another limitation is that the students' naive concepts will present themselves time and again, which shows that the variable of students' naive concepts is uncontrollable.

9.5 Conclusions

In the study, the integrated mode of computer simulation to scientific discovery learning is explored. The results show the following: (1) Compared with the mode of scientific discovery learning in real-life experience, the integrated model of computer simulation in scientific discovery learning shows very significant improved effects upon the students' mastery of the principle knowledge. (2) Compared with the mode of scientific discovery learning in real-life experience, the integrated mode of the computer simulation in scientific discovery learning shows no significant improved effects upon the students' intuitional understanding. Based on the in-depth analysis, it is found that the integrated mode shows significant improved effect for the high-score group, approximate significant improved effect for the medium score group, and no significant improved effect for the low-score group. (3) Compared with the mode of scientific discovery learning in real-life experience, the integrated mode of computer simulation in scientific discovery learning shows significant improved effect on the students' flexible application. (4) The students' basic physics knowledge has very significant effects on their scientific discovery learning. (5) The integrated mode of computer simulation in scientific discovery learning takes good advantage of the computer-simulated situations and the real-life experiences, but it also has some limitations in the students' understanding of the nature of the experiments and in testers' grasping of the variations of students' naive conceptions.

References

Chen, Q., & Liu, R. (1997). *The applications of information technology in education* (pp. 5–6). Beijing: Posts & Telecom Press. In Chinese.

Goodyear, P. (1992). The provision of tutorial support for learning with computer-based simulations. In E. D. Corte, M. C. Linn, H. Mandl, & L. Verschaffel (Eds.), *Computer-based learning environments and problem solving* (pp. 391–409). Berlin: Springer.

Jong, T. D., & Njoo, M. (1992). Learning and instruction with computer simulations: Learning processes involved. In E. D. Corte, M. C. Linn, H. Mandl, & L. Verschaffel (Eds.), *Computer-based learning environments and problem solving* (pp. 411–427). Berlin: Springer.

Li, T. (2009). *An experimental study on the model of the application of computer simulation to scientific discovery learning in middle school physics* (technical report) (In Chinese). Chongqing: The Research Center of Science Education of Southwest University.

von Joolingen, W. R., & de Jong, T. (1997). An extended dual search space model of scientific discovery learning. *Instructional Science, 25*(5), 307–346.

Wellington, J. (1999). Multimedia in science teaching: Friends or foe? *Physics Education, 34*(6), 351–359.

Zhang Jianwei, & Chen Qi. (2001a). The state of the art of scientific discovery learning. *Advances in Psychological Science, 9*(4), 289–294.

Zhang Jianwei, & Chen Qi. (2001b). *Scientific discovery learning based on computer simulation: inherent precondition and learning support* (In Chinese). In Proceedings of the 9th annual conference of Chinese psychological society. Guangzhou.

Chapter 10
An Empirical Study of Factors Influencing the Professional Development Levels of Elementary Science Teachers

Chang-chun Lin and Xin Shou

Abstract Based on a questionnaire survey and using hierarchical linear modeling, the aim of this study was to empirically investigate factors influencing the levels of professional development of science teachers in elementary schools at both the individual and the school level. The study found that seniority of teachers, academic diplomas, and job title were the three main individual factors influencing the professional development of science teachers. Schools played a key role in motivating the level of professional development of science teachers, and the levels of professional development varied greatly between schools. Differences between schools was one factor influencing the unevenness of science teachers' professional development. The mechanism by which school teachers were evaluated provided the opportunity for teacher development; teacher training was another important factor in the uneven levels of professional development. Some measures to reduce differences in levels of professional development and to strengthen the ranks of science teachers would be to develop multi-evaluation mechanisms, carry out school-based teaching and research, and further improve the training of science teachers.

Keywords Primary school science teacher • Professional development • Hierarchical linear model • Empirical research

---

C. Lin (✉)
Primary Teacher Education Research Center,
Chongqing Normal University, Chongqing, China
e-mail: lcc5360@163.com

X. Shou
College of Chemistry, Chongqing Normal University, Chongqing, China

B. Zhang et al. (eds.), *International Conference on Science Education 2012 Proceedings: Science Education: Policies and Social Responsibilities*,
DOI 10.1007/978-3-642-54365-4_10,

10.1 Introduction

A new round of basic education curriculum reform has higher demands on teachers' professional development, thus, how to conduct teacher's professional development nowadays has become an urgent issue. In order to establish learning systems for teacher professional development grounded in school-based research, Shanghai Education (2005) proposed the creation of "the system construction based on school research." Peng (2004) explored cooperation between college high schools and primary schools to expand the function of each, based on Professional Development Schools (PDS) and Teacher Development Schools (TDS). Zhong (2005a) conducted a preliminary exploration to construct a teachers' professional development school and the overall structure and strategies of a teachers' professional development school. Cai (2006) explored a new mode of teacher education and teacher professional development. Ding (2011) has undertaken a project investigating and creating a qualitative description of the current level of national primary and secondary school teacher professional development.

In recent years, common understanding of teacher professional development is that a teacher who goes through broad learning activities and professional interaction improves his/her professional knowledge and skills. At the same time, improved teaching practice can also improve individual social and emotional literacy. As a comprehensive science curriculum implementer, promoter, and researcher, the professional development of elementary school science teachers directly affects the development of the elementary school science curriculum and the quality of elementary school science teaching. At present, there are some descriptive studies of elementary school science teacher professional development: Pan (2005) analyzed factors that influence professional development of science teachers; Zhong (2005b) discussed the composition content of science teachers' professionalism; Cai (2007) investigated science teachers' present scientific literacy and scientific nature view at elementary schools in the Zhe Jiang province; Bo (2011) discussed the four course modules of the continuing education curriculum system for elementary science teachers.

The authors found that most research related to current domestic elementary science teachers' professional development in China were limited to descriptive analyses; empirical studies discussing factors influencing professional development of elementary science teachers are rare. This paper is based on questionnaires investigating the present situation of some science teachers in Chongqing. We used an applied hierarchical data statistical method that is commonly used for senior statistical analysis in social science—the hierarchical linear model (HLM)—in an attempt to discuss the two-layer factors that influence science teachers' professional development objectively and quantitatively. At the same time, we checked the validity of multiple linear model suitable for the study, making some suggestions on elementary science teachers' professional development.

It is not only individual factors but also different school backgrounds that are key factors influencing the professional development of elementary science teachers. There may be huge professional differences among science teachers from different schools. Based on the above hypothesis, utilizing the HLM, we analyzed whether professional differences are significant. According to data analysis from the model, we objectively and quantitatively discuss some significant factors that influence the professional development of elementary science teachers at the school level.

10.2 Research Method and Variable Selection

10.2.1 Research Methods

10.2.1.1 Questionnaire Survey

This study presents results mainly from questionnaires. The survey included 39 elementary schools from 9 of the Chongqing urban areas and their surrounding areas. A total of 243 questionnaires were collected, 215 of which were valid; the effective response rate was 88.5 %.

The survey instrument was the "elementary science teachers' professional development present situation investigation" questionnaire. This questionnaire consisted of three parts. The first part comprised participants' basic information, including gender, age, school age, educational background, professional titles, whether they are full-time division science teachers, etc. The second part comprised the knowledge and ability structure of the participants. The knowledge structure included five dimensions: professional knowledge, education science knowledge, related discipline knowledge, instrumental knowledge, and humanistic knowledge. The ability structure included four dimensions: basic teaching ability, scientific experiment teaching ability, innovation education ability, and information technology education ability. According to the above content, this paper is drawn from each elementary science teachers' professional development level score. The third part of the questionnaire covered the professional evaluation and training situation, including the elementary science teacher evaluation system based on school teachers' participation in science course training.

The first and third parts of the questionnaire recorded information about the teachers and their schools; part 2, knowledge structure and ability structure, was the core of the questionnaire. This classification was based on the document *elementary teachers' professional standards* issued by the Ministry of Education in February 2012, which included professional knowledge and professional ability. According to the document, we formulated knowledge structure and ability structure that elementary science teachers should possess. Items were measured on a Likert scale, where '5, 4, 3, 2, and 1' represent 'know better, know well, know, know less, or unknown', respectively. A teacher's total score was his/her professional development level. Meanwhile, science teachers from the same school were allocated to the same group and received a group number; this established a bi-level linear model to analyze individual factors and school factors that influenced science teacher professional development.

10.2.1.2 Hierarchical Linear Model (HLM) Analysis

In many studies, sampling often comes from different levels and units, which enables the data to span a multiple-level research problem. To solve these problems required a new data analysis method—HLM analysis.

The HLM, used to analyse data with nested structure characteristics, was mainly initiated in the 1990s and developed by Professor Harvey Goldstein (2003) of London University and Professor Stephen W. Raudenbush (2002) of Michigan University. It is widely used in the social sciences fields. In recent years, the main trend in empirical research in the education research field has been to use multiple linear models for advanced statistical analysis. Liu and Meng (2002) analyzed the impact of context variables on teaching effect. According to set up two-level model of students and teachers, Chen (2011) analyzed teacher quality and its influencing factors in Western rural China among primary and secondary schools. By constructing a two-level value-added model, Liang (2011) accurately measured the influence of teachers on the academic development of students. Using the HLM, Ai (2008) discussed university teachers' scientific research level.

Compared with linear analysis—such as linear regression and analysis of variance (ANOVA)—which rely on the ordinary least squares (OLS) method for parameter estimation, the HLM uses shrinkage estimation, which is more stable and accurate. For example, when there is only a small number of individual samples in the second variable unit (such as this study surveying science teachers' individual differences in quantity), small sample-based regression estimate is not stable, and the HLM uses two estimations of weighted integration (such as in this study, one from a single school OLS estimate, the other is each school of data weighted least squares estimate) as the final estimate, rendering the conclusions more dependable.

For a simple bi-level linear model, the basic equation is as follows:

Level-1 Model

$$Y_{ij} = \beta_{0j} + \beta_{1j} * \left(X_{1ij}\right) + r_{ij} \qquad r_{ij} \sim N\left(0, \sigma^2\right)$$

Level-2 Model

$$\beta_{0j} = \gamma_{00} + \gamma_{01} * W_{1j} + u_{0j} u_{0j} \sim N\left(0, \tau_{00}\right)$$
$$\beta_{1j} = \gamma_{10} + \gamma_{11} * W_{1j} + u_{1j}$$

The merger of two-level linear models is expressed as follows:

$$Y_{ij} = \gamma_{00} + \gamma_{01} * X_{1ij} + \gamma_{01} * W_{1j} + \gamma_{01} * X_{1ij} * W_{1j} + u_{0j} + u_{1j} * X_{1ij} + r_{ij}$$

In this study, Y_{ij} means the score of science teacher's professional development level of the *i*th science teacher of the *j*th school. X_{1ij} means the predictor variable (e.g. in this study school age, education background, and professional title) of the *i*th science teacher of the *j*th school. W_{1j} means layer-two predictor variable (such as the system of 'teacher evaluation' in school) of the *j*th school. For the layer-1 model, β_{0j}, β_{1j} means regression straight line intercept and slope of dependent variable of the *j*th science teacher, respectively; r_{ij} means the measurement error of the *i*th science teacher of the *j*th school. For the layer-2 model, γ_{11}, γ_{01} means regression straight line intercept and slope of layer-2 variable W_{1j} to intercept β_{0j} respectively. u_{0j} means the intercept of random error term which brought about by layer-2 variable W_{1j}. γ_{10}, γ_{11} means regression straight line intercept and slope of layer-2 variable W_{1j} to intercept β_{1j}, respectively. U_{1j} means the intercept of random error term which was brought about by the layer-2 variable W_{1j}. In addition, the stochastic error term r_{ij}, u_{0j} of the first and layer-2 model obeys the normal distribution, which mean value is 0, the variance is σ_2, τ_{00}.

10.2.2 Correlated Variables of Descriptive Analysis

A lot of the empirical research abroad shows that there is an obvious relationship between teacher's professional development level and their individual difference. So, it is necessary to know science teachers' pre-service education and their post-career condition. According to the questionnaire survey statistics, Table 10.1 shows elementary science teachers' school age, age, and professional title structure.

From Table 10.1, we can see that, 95.2 % of science teachers have a college degree or higher. Science teachers who have technical secondary school degrees and other only account for 4.8 %. It shows that elementary science teachers' education generally reach national standards. Science teachers who have a professional background in science education and science departments only account for 30.7 %. The phenomenon of "teach not learned" is very serious.

Statistics regarding the school age of teaching science show a fluidity in our team of science teachers, and a lack of fixed teachers teaching science; this directly influences the professional development of elementary science teachers.

Table 10.1 also shows that the professional title structure of elementary science teachers follows a normal distribution, and it is basically reasonable.

10.3 Empirical Results Analysis

10.3.1 Analysis of Variance Model

The ANOVA model, in which there is no predictor variable at the first and second layer aims to distinguish the difference between object individual differences researched and between-group differences compared, temporarily take no account of control variable to the influence of the dependent variable. In this case, using Null model that the first and the second layer are no predictor variable is enough.

Table 10.1 Science teachers' education, teaching age, professional title distribution (%)

Pre-service education background	Master degree	Bachelor degree	College degree	Technical secondary school degree	Other	
	1.2	57.8	36.2	4.4	0.4	
School age of teaching science	<5 years	5–10 years	11–20 years	21–30 years		
	62.7	20.7	13.2	3.4		
Professional title	Boffin	Senior Secondary	Senior primary (middle school level 1 title)	Primary school level 1 title	Primary school level 2 titles	
	1.9	21.6	44.6	30.2	1.7	
Professional background	Science education	Science department	Arts	Music education, physical education, and art education	Elementary education	Other
	10.7	20.0	33.5	4.2	26.0	5.6

Table 10.2 Under the background of school elementary science teachers' professional development level variance analysis model

Random effect		Standard deviation	Variance component	Degree of freedom	Chi-squared value	*P* value
INTRCPT1	u_0	9.88162	97.64650	30	36.34886	<0.001
Level-1	r	13.04318	170.12454	–	–	–

The ANOVA component model equation is as follows:

Level-1 Model

$$Y_{\mathrm{ij}} = \beta_{0j} + r_{ij} \mathrm{r}_{ij} \sim N\left(0, \sigma^2\right)$$

Level-2 Model

$$\beta_{0j} = \gamma_{00} + u_{0j} u_{0j} \sim N\left(0, \tau_{00}\right)$$

Because the research object is elementary school science teachers from different schools, differences in the level of professional development cannot be regard as a one-layer factor. The main purpose of the ANOVA model is to test whether or not the proportion of each layer variance is significant; if the variance analysis model parameter estimation results refuse the null hypothesis (H_0: $\tau_{00} = 0$), i.e., if the second model of random error term variance is significant, we can undertake multiple linear analysis.

The p-value is <0.01 (measured $p < 0.001$) (Table 10.2), meaning that variance is not equal to zero, showing that remarkable differences exist in science teachers' professional development level between different schools. In addition, reliability of the sample average β_{0j} is 0.635, which can also accept, explaining the actual average with sample is reliable. Using robust standard deviation square composition analysis conditions, interclass correlation coefficient calculation p is 0.3647, which explains that the differences among science teacher's professional development level of different schools has reached 36.37 %; we can establish bi-level linear model of schools background level.

10.3.2 Random Regression Analysis that Do Not Include the Second Variable

On the basis of HLM7.0 software processing data, the preliminary analysis shows that elementary science teachers' professional development level and teachers' personal level test results reached the statistically prescribed significance level. Through the ANOVA model calculation and analysis, there are three explanatory variables (school age, education background, and professional title) influencing the dependent variable (teachers' professional development level), in which exist big

Table 10.3 Regression analysis of not including variable of layer-2

Variable of layer-1	Regression coefficient	Standard error	*t*-test	Variance component and χ^2 test
School age	0.4745	0.1545	3.071*	0.0755**
Education background	1.1922	0.5513	2.163**	0.2806*
Professional title	−0.0184	0.3479	0.053	0.0673*

Note: *$P < 0.05$, **$P < 0.01$

differences among different schools (Table 10.3). Then establishing a two-layer analysis model to investigate the influence of school as an independent variable to teachers' professional development level.

According to Table 10.3, in the control the teacher's gender factors, education background ($p < 0.01$) and school age ($p < 0.05$) has the obvious positive predictable effect, regression coefficient are 1.1922 and 0.4745, respectively. That is to say, the higher the education, the more conducive to science teacher's professional development; with the increase in school age, novices gradually grow into experts, this also is helpful to professional development. Professional title is a negative factor ($\beta = 0.0184$), but weakening the role of teachers' professional development was not significant ($p > 0.05$).

At the same time, Table 10.3 also provides variation information of each variable's regression effect under the background of different schools. Null model analysis has shown that there is obvious variation among the three variables of regression coefficient in the school background ($\rho = 0.3647$). For example, education background in science teachers' professional development level of regression coefficient is 0.7468. All other variables kept constant, it means education background raises 1, science teacher's professional development level will rise by an average of 0.7468, but the extent of the increase in each school may not be the same ($p < 0.01$).

As mentioned, the main role of the variance analysis model is to determine whether the regression coefficient of layer-1 behaves significantly different on layer-2, and the difference is the difference in the variance. So, there is no relationship between whether the regression coefficient of layer-1 behaves significantly and building the layer-2 model, we mainly analyze the null model's variance significantly or not to set up the layer-2 model. In Table 10.3, although professional title to science teacher professional development level of regression coefficient was not significant ($\beta = 0.0818$, $p > 0.05$), variance of regression coefficient of professional title behaves significantly in the school background, we still need to take the professional title of the regression coefficient as dependent variable into the layer-2 model.

10.3.3 Complete Model

Considering influence of the layer-2 variable of regression effect on the layer-1 variable of slope and intercept and deviation statistics of layer-2 model cannot complete analysis, we should weaken of the influence of non-school factors on the science teacher professional development level as far as possible, making the influence of school become an independent "residual", in the "residual" sample size 1 we can estimate teachers' professional development level from the school level and individual level. The layer-2 of the intercept can best embody the elementary science teachers' professional development level, so we assume that layer-2 variables have a significant effect on it. Similarly, assuming layer-2 of variable, which belong to the model random item within the scope of existence have appreciable impact on regression coefficients of layer-1 of variables. So, the layer-2 of intercept also incorporated into all the layer-2 response variables to analysis layer-2 intercepts' positive or negative effect on layer-1 response variable of regression coefficient.

Elementary science teachers' professional development level-2 complete model based on school level:

Level-1 Model

$$F_{ij} = \beta_{0j} + \beta_{1j} * \left(B_{ij}\right) + \beta_{2j} * \left(D_{ij}\right) + \beta_{3j} * \left(E_{ij}\right) + r_{ij}$$

Level-2 Model

$$\beta_{0j} = \gamma_{00} + \gamma_{01} * \left(X_j\right) + \gamma_{02} * \left(Y_j\right) + \gamma_{03} * \left(Z_j\right) + u_{0j}$$

$$\beta_{1j} = \gamma_{10} + u_{1j}$$

$$\beta_{2j} = \gamma_{20} + u_{2j}$$

$$\beta_{3j} = \gamma_{30} + u_{3j}$$

B_{ij}, D_{ij}, and E_{ij} means school age, education background, and professional title in layer-1, respectively. X_j, Y_j, Z_j means the satisfaction of the school's current teacher evaluation mechanism, professional development opportunities provided by the school, and school organization science teacher training times in layer-2, respectively. In determining the significant prediction variables in layer-1, we have already got rid of some dependent variables, which regression coefficient and variance component are not significant ($p > 0.05$) and get three layer-1 variables above. Layer-2 variable selection mainly consider from the school background level, in order to comprehensively analyze the influence of other layer-2 variables on elementary science teacher professional development level, we bring γ_{01} and γ_{03} into the analysis process, the regression coefficient of which is not so significant. According to the specific complete model parameter estimation, the calculation results are shown in Table 10.4.

As shown in Table 10.4, school background has a significant effect on science teacher level of professional development (γ_{00}, $p < 0.01$). Specifically, single school teacher evaluation mechanism is not conducive to the professional development of science teachers ($\gamma_{01} = -0.1342$), but this kind of negative influence is not significant ($p > 0.05$). All kinds of professional development opportunities that are offered by schools have a significant positive effect on the professional development of science teachers ($\gamma_{02} = 0.7415$, $p < 0.01$), all kinds of professional development opportunities that are offered by the school raises 1, science teacher's professional development level will rise by an average of 0.7415. So, schools should actively organize various

Table 10.4 Elementary science teachers' professional development level-2 complete model based on school level

Fixed effects	Regression coefficient	Standard error	*t*-test	Random effect	Standard deviation
γ_{00}	38.9755	0.8470	4.601**	u_0	9.217
γ_{01}	–0.1342	0.1342	–1.001	u_1	8.066
γ_{02}	0.7415	0.0590	12.572**	u_2	15.561
γ_{03}	–0.0411	0.1177	–0.351	u_3	17.373
γ_{10}	0.6823	0.2678	2.548*	R	10.594
γ_{20}	1.2581	0.5480	2.296*	Deviation statistics	637.012
γ_{30}	–0.0339	0.4922	–0.475*	d.f.	42

Note: $*P<0.05$, $**P<0.01$

teacher skills activities and perfect the teacher training system to maximize science teachers' professional level. The number of teacher training has little effect on their professional development ($p>0.05$), even both was negatively correlated, but its effect on weakening science teacher professional development is not significant.

Under the background of school, teacher of school age will have a significant impact on their professional development (γ_{10}, $p<0.05$). On one hand, with the end of the pre-service learning, novice teachers being qualified full-time teachers becomes their responsibility must seek for advice modestly, owning strong sense of motivation and professional development, this in itself promotes their professional development; on the other hand, in order to enable novice teachers to grow rapidly, a variety of development platforms provided by the school will also promote their professional knowledge structure and ability structure to improve rapidly. Teachers who are highly educated obtain a higher professional level, and the positive influence has reached the significant level of stochastic term (γ_{20}, $p<0.05$). Education background raises 1, average of science teacher's professional development level will raise 1.258. It is worth noting that its regression coefficient is the largest of all fixed effects ($\gamma_{20}=1.2581$), maybe more learning experience gives teachers a more solid theoretical foundation to use education teaching theory method effectively in their teaching and research, and enhances their professional accomplishments.

In addition, empirical analysis shows that teachers' professional titles have a negative correlation to their professional development and this kind of negative relationship is significant ($p<0.05$). A possible explanation for this is that, with the improvement in professional title, their professional knowledge and professional skills have tend to improve and they consider teaching and management to be easy. Job burnout will also occur, thus leading to a non-significant professional development level. Therefore, looking for new directions in professional development is key for science teachers who have high-level professional titles to break through the bottleneck of professional development. Measures such as combining teaching, research and management could improve teaching on one hand; and such measures could also promote teaching research. When the three aspects join force, a "partners relationship" can be formed (Herne 2009). Such community of practice eventually promotes teacher professional development.

10.4 Conclusions and Suggestions

10.4.1 Conclusions

Based on the research of schools' influence scale on science teachers' professional development and individual influence effect index (that is the two-level model analysis established above), we can gain a relatively clear understanding that school and individual both play a role in promoting elementary science teachers' professional development.

1. From the complete effect model analysis, we can draw that, as an important individual factor, there is a positive correlation between pre-service education backgrounds and science teachers' professional development.
2. In different schools, there is a big difference between the relationship of science teacher of school age and their professional development ($p < 0.01$). Simultaneously, we should strengthen contact between awarding professional titles and science teacher's specialty literacy; rely on awarding professional titles to promote professional development, use professional development level as a basis for professional titles.
3. School as important layer-2 variable after individual background still plays a role that cannot be ignored in improving science teachers' professional levels. Diversified methods of "teacher evaluation" is more conducive to science teachers' professional development. To teacher professional development, the response regression coefficient of multi-level teacher development opportunity is 0.7415, i.e., in the control of individual-level factors and non-teacher factors of school level, if the index of teacher development opportunities offered by school were all to improve by 1, professional development level of science teachers who come from two different schools will increase by 0.7415.

All in all, based on the empirical method of shrinkage estimation of HLM, setting up two-level forecast analysis model, the paper has surveyed and proved that school background is one of the important reasons of differences and unevenness in science teachers' professional development, In addition to the individual differences of science teachers.

10.4.2 Suggestions

1. Build a wide range of school-based science teacher evaluation system from the science teacher knowledge structure and ability structure. HLM analysis results show that most science teachers are not satisfied with school-based teacher evaluation ($\gamma_{01} = -0.1342$), this is adverse to science teachers' professional development.

   Generally speaking, we should use developmental evaluation idea as the guidance to design science teacher evaluation index and develop evaluation criteria; based on formative and developmental theory to study the implementation process of evaluation; let teacher evaluation borrow from job performance evaluation in management science to study the science teacher evaluation methods; according to the evaluation of function and efficiency, conduct the results of the evaluation of science teachers.

From the discipline characteristics of the science curriculum, science curriculum covers multidisciplinary subject knowledge of material science, life science, earth and space science, etc. Therefore, evaluation to science teacher must have a wide perspective, we should establish peer evaluation system in science concept, science teachers should also be hands-on operation to comprehend general process, principle, method of science inquiry and based on it to evaluate. Meanwhile, science teachers still need to have gained some understanding of some auxiliary scientific knowledge and scientific theory to structure a diversified evaluation system which set inquiry as the core, and related discipline knowledge as the foundation.

2. Regard school-based research as a connection point, setting up the bridge between professional title evaluation and science teachers' professional development. HLM analysis results show that the degree of contact between science teacher's title and their professional development level needs to be improved ($p > 0.05$). Professional knowledge and professional skill level constantly improved and job burnout followed is a main reason leading to this result, so looking for new direction of science teacher professional development and overcome job burnout is the key to breaking through the bottleneck of professional development.

   School-based research is helpful to optimize teaching ideas, and improve the ability to solve practical problems in teaching, innovate and improve teaching activities, raising professional quality. Research has shown that most science teachers have the desire to actively participate in school-based teaching and research activities, so timely conforming to the science teachers' participation in the research, based on inquiry teaching, focus on improving senior title science teacher's teaching research ability. For low titles of novice, they should apply scientific theory and method to find phenomena and problems in teaching and relevant activities consciously, purposefully and designedly, exploring and understanding the law of science teaching. Besides, regarded combination of teaching and teaching research as a breakthrough, research content should be based on the discipline of teaching practice, making school-based research drive them to conduct action research.

3. Further perfect the primary science teacher training mode. HLM analysis results show that the degree of contact between science teacher training times and their professional development level needs to be improved ($p > 0.05$). The reason for this result is that most schools do not attach importance to the science curriculum, fewer science teachers participate in training, and there is no obvious effect of training, training content is too theorized, training policy is not perfect, etc.

   So, while increasing investment in science teacher training, we should innovate content, mode, efficiency, and evaluation of teacher training. The principle of training should be in line with the spirit of 'training content diversify, training evaluation normalization', satisfying the actual needs of science teachers. Professional training should contain completely professional knowledge, professional ability, teaching ideas, teaching methods, scientific value, information technology education, and other aspects. Training content should not only update science teaching ideas, but also science inquiry (Huang 2007) such as 'lesson analysis'. Training methods should be effective, such as 'demonstration lessons', assessment methods can combine teaching design case, manufacturing courseware, researching topics (essay), and showing the charm of classroom teaching.

References

Ai, W. (2008). Study of using the hierarchical linear model of university teachers' scientific research level (in Chinese). *Statistical Observation, 7*, 95–99.

Bo, L. (2011). Elementary science teacher continuing education curriculum system (in Chinese). *Continue Education Research, 9*, 122–124.

Cai, B. (2006). Based on teachers' professional development of teacher education mode of practice (in Chinese). *Global Education, 3*, 41–46.

Cai, T. (2007). Elementary science teachers' scientific literacy and scientific nature view present situation investigation and understanding in Zhejiang province (in Chinese). *Global Education, 8*, 55–58.

Chen, C. (2011). An empirical analysis of teacher quality and its influence factors in Western rural China among primary and secondary schools (in Chinese). *Teacher Education Research, 5*, 61–65.

Ding, G. (2011). Report of Chinese primary and middle school teachers' professional development condition investigation and policy analysis (in Chinese). *Educational Research, 3*, 3–11.

Goldstein, H. (2003). *Multilevel statistical models* (3rd ed.). New York: Oxford University Press Inc.

Herne, S. (2009). *Learning to teach: Teachers' professional development guidance*. Shanghai: East China Normal University Press.

Huang, S. (2007). Analysis and suggestions of elementary science education teachers' current situation (in Chinese). *Journal of Teaching and Management, 9*, 28–29.

Liang, W. (2011). Based on students' academic achievement of teachers' quality evaluation (in Chinese). *Peking University Education Review, 7*, 106–120.

Liu, H., & Meng, D. (2002). Hierarchical analysis of the impact of context variables on the teaching effect (in Chinese). *Psychological Development and Education, 4*, 70–75.

Pan, S. (2005). An analysis of elements of restricting synthetically science teachers' professional development (in Chinese). *Teacher Education Research, 5*, 35–40.

Peng, S. (2004). PDS and TDS: The effective way of teachers' professional development (in Chinese). *Teacher Education Research, 6*, 7–12.

Raudenbush, S. W. (2002). *Hierarchical linear models: Application and data analysis methods* (2nd ed.). Thousand Oaks: Sage.

Shanghai Education. (2005). The teacher learning culture—talk with Professor Gu, Vice President of Shanghai science institute (in Chinese). *Shanghai Education, 5*, 24–28.

Zhong, Z. (2005a). The construction of teachers' professional development school (in Chinese). *Teacher Education Research, 4*, 9–12.

Zhong, X. (2005b). Challenge and development: On science teachers professional quality (in Chinese). *Curriculum Teaching Material and Method, 8*, 79–83.

Chapter 11
Impact Analysis of Student-Centered Inquiry-Based Project and Implications on Standards of Science Curriculum in Pakistan

Alyas Qadeer Tahir

Abstract This paper aims to analyze the impact of baseline and end-line surveys in terms of its inputs and achievements during a 3-year (2009–2012) project on "student-centered and inquiry-based (SCIB) learning" sponsored by the Japan International Cooperation Agency (JICA). The activities of the project included 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 the 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-differences estimation. The result of the analysis advocated for an infrastructure of training of science teachers which supports in delivering the lessons effectively and making the science activities interesting. 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 underpins 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 can 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.Q. Tahir (✉)
National Institute of Science and Technical Education Ministry of Education,
Sector H-8/1, Islamabad 44000, Pakistan
e-mail: ilyasqadeer@yahoo.com

B. Zhang et al. (eds.), *International Conference on Science Education 2012 Proceedings: Science Education: Policies and Social Responsibilities*,
DOI 10.1007/978-3-642-54365-4_11,

11.1 Introduction

The National Education Census (Govt. of Pakistan 2005) indicated that there were no content standards for curriculum as well as professional standards for in-service education of teachers in Pakistan. The science curriculum does not cater to the diverse conditions in the education sector, as well as the variations within the geographical breadth of Pakistan (Shami 2010) and meeting the goals of science education globally (Avargil et al. 2012). For this background in view, a comprehensive review of elementary science curriculum for grades 4–8 was initiated in 2005. The experts of National Curriculum Council reviewed the scheme of studies, drafted the elementary science curriculum after comparing with similar type of curricula of other countries. The current elementary science curriculum received the present form after exhausting a long consultative process of interaction and discussion with all stakeholders including working science teachers, administrators, educationists, curriculum experts, and students (Govt. of Pakistan 2009). The lesson learned as a consequence of various studies (Govt. of Punjab 1998; Iqbal 2006; Naveed 2010; Tahir 2005) on teacher education for elementary school science teachers of Pakistan is the deficiency in terms of delivery through an inquiry and concept-building approach (Anderson et al. 1982; Mechling and Oliver 1983; Shymansky et al. 1990). In an effort to assist Pakistan to begin with a holistic review of elementary science lessons and establish a training model for the in-service science teachers, the Japan International Cooperative Agency (JICA), Pakistan, took an initiative in launching a 3-year project, namely, "student-centered and inquiry-based (SCIB) learning." The project was mainly based on development of lesson plans of general science curriculum for grades 4–8 emphasizing the concept of student-centered and inquiry-based learning. This paper focuses on objectives, programs, and achievements followed by a baseline and end-line survey reports of the SCIB project.

11.2 SCIB Project

The main objective of the project was to develop a worthwhile teacher training package that motivates science teachers to use lesson plans developed on inquiry approach for implementing in Islamabad Capital Territory (ICT) in five pilot clusters of schools and in provinces of Pakistan. As an output of the project set forthwith according to JICA report (2009), "the project was to: (1) develop SCIB teaching plans for grade 4–8 science; (2) equip master trainers with skills and knowledge to use SCIB lesson plans; (3) identify necessary interventions for effective teacher training through pilot activities in ICT; (4) share experience of model teacher training among other educational related stakeholders and to increase their interest in SCIB." As a result of achievement of the project, the SCIB teaching plans were developed for grades 4–8 in both English and the national language "Urdu." The DVDs and books of these lesson plans were distributed to

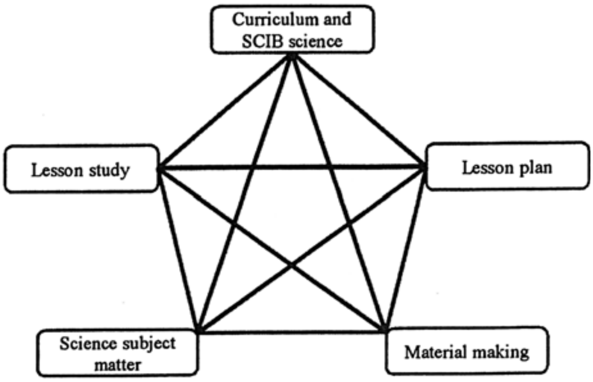


Fig. 11.1 Interlinked areas for teacher training of SCIB project

the teachers of pilot cluster schools of ICT and education departments of the provinces. The teaching plans comprised of unit plan, lesson plan, subject matter, marking material, and ways of assessment. One hundred ninety-three master trainers were trained and equipped with science process skills and knowledge of science to deliver SCIB science lessons. These trainers were conducting training specifically in material making, lesson plan improvements, and integration of concept building of science principles. The training content covered five interlinked areas focusing on the general science curriculum and lesson plan study in order for the participants to understand the teaching principles and methods to follow the curriculum (JICA 2012) as illustrated in Fig. 11.1. Twenty selected officers engaged in the project were sent to Japan for training in the activities related to SCIB and in the area of management. Some important inputs for suitable teacher training were identified through pilot activities in ICT. One of the major achievements of this project was to share the experience of model SCIB teacher training among other education-related stakeholders, and their interest in SCIB was increased. For this, a number of forums, awareness-raising meetings, and promotional videos were organized in the provinces and in ICT (JICA 2012).

11.3 Standard-Based Elementary Science Curriculum

The overall goal of science education set forth in Pakistan is to develop scientific literacy as a "result of context-based learning related to real-world problem as defined by AAAS (1990), NRC (1996), Dori and Herscovitz (1999), Kaberman and Dori (2009), Krajcik et al. (2008)." Therefore, science education which strives for scientific literacy is intended to focus on inquiry-based curricula (Sadler and Zeidler 2009). According to the national science curriculum document (Govt. of Pakistan 2006), "three basic processes used to answer these questions; scientific inquiry addresses 'Why' questions; 'How' questions are answered by engaging in the problem solving and 'should' questions are answered by engaging in decision making. The framework

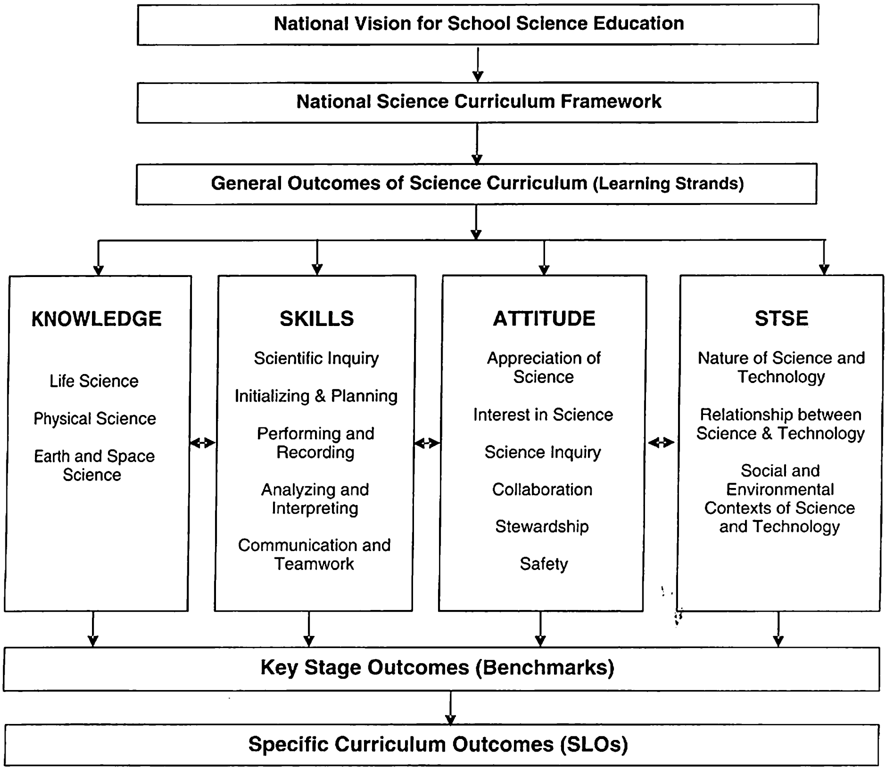


Fig. 11.2 Conceptual map of the national science curriculum for grades 4–8

of elementary science curriculum provided a set of well-defined General Science Outcomes (Learning Strands and Content Standards), key stage Curriculum Outcomes (Benchmarks), and specific Curriculum Outcomes (Student's Learning Outcomes – SLOs)." The conceptual map for the curriculum outcomes is illustrated in Fig. 11.2 (Govt. of Pakistan 2006).

Accordingly, "six major learning areas as learning strands selected for this curriculum includes: Life Science, Physical Science, Earth and Space Science, Skills, Attitude and Science, Technology, Society and Environment (STSE). The inter-graded strands are interwoven with the three contextual strands (Knowledge, skills and attitudes). The description of contextual or content strands as content standards in this curriculum outlined the subject areas into Life Science, Physical Science and Earth and Space Science. These standards embrace with the learning unit, theories, concepts, principles and practical work that are essential to an understanding of each science area (Ullah 2010). Benchmarks are the statements that identify the learning outcomes of students what they are expected to know, be able to do and value by the end of high schools (AAAS 1993)." In this curriculum, two sets of benchmarks have been selected. First are the benchmarks for the grade cluster IV–V (what learning outcomes will be expected from all students at the end of grade V in the six (6) learning strands), while the second set of benchmarks is for the grade cluster of VI–VIII (what learning outcomes will be expected from all students at the end of grade VIII in the six (6) learning strands). Another important component of elementary science curriculum is the student's learning outcomes (SLOs) which are basically the incremental steps toward accomplishment of benchmarks organized around the standards and listed for each grade level as stated advance in their knowledge, skills, attitudes, and applications.

11.4 In-Service Teacher Training

The professional development of teachers, which goes through induction in their first year of teaching, should continue throughout their career (Harlen 1990). For a system to deliver quality education, particularly in a world of changing needs and expectations, it is essential that teachers and heads of institutions have access to, and participate regularly and frequently in, continuing professional development or in-service education. In-service education for teachers is seen as an appropriate means of assisting the teacher to meet classroom challenges (Harris and Fasano 1988). It was with this in mind that the Education Policy 1979 (Govt. of Pakistan 1979) stated that every teacher should have the opportunity of in-service training at least once every 5 years. This was modified in the 1992 Education Policy (Govt. of Pakistan 1992) in which it was stated that a regular in-service program would be launched for teachers at all levels. Education Policy 2009 (Govt. of Pakistan 2009) elaborated the need of professional training of in-service teachers through a program organized on a 3-year cyclic basis. The policy linked the progress in career of in-service teachers to enhancement in their capabilities and skills through training during the job. The policy specifically recommended that in-service teacher training in science subjects shall be based on real-life situation, use of science kit, and provision of resources of training to all primary and middle schools teachers of the country. The World Bank in its report on "Teachers Training" (Haddad 1985) emphasized the utility of in-service education in developing countries. An effective form of in-service education according to the report is to produce a well-designed teacher's manual and to provide it to the teacher along with the textbook. The report concludes that "There is some evidence that the effect of in-service training is strongest when it is relatively participatory and responds to the needs that teachers themselves have identified and weakest when it consists of experts telling the teachers what to know." Bhatti (2009) and Farooq (2006) have identified "delivery of lessons" as the main weak area of Pakistani teachers. According to Azhar (2010), the present system of in-service training of teachers in Pakistan is not significantly contributing toward their professional development especially in terms of delivery of effective lessons by science teachers. The present structure for in-service education in the provinces leaves much to be desired. In the three provinces of Sindh, NWFP, and Balochistan, the Bureau of Curriculum and Extension Services and in Punjab the

Directorate of Staff Development have responsibility for providing in-service education for all levels, subjects, and cadres of teachers. Obviously, it is not possible to expect them to reach every teacher at every level, and the organization of in-service education needs to be reassessed especially through the experience of SCIB project.

11.5 Baseline and End-Line Surveys for Impact Analysis

11.5.1 Objective of the Analysis

The main objective of this analysis was to examine the impacts of the SCIB project, comparing the data collected during the baseline survey for impact analysis (BLSIA) conducted in the beginning of the project, i.e., October 2009, and those collected during the end-line survey for impact analysis (ELSIA) in October 2011 (JICA 2012).

11.5.2 Research Questions of the Analysis

Impact analysis examined the following expected impacts of the project:

1. Whether project activities improve the teacher's understanding, skills, and motivation on SCIB science lessons
2. Whether trained teachers improve the teaching-learning process of science lessons
3. Whether students increased their interest and motivation in pilot schools

11.5.3 Indicators of the Analysis

Table 11.1 shows the summary of indicators for impact analysis. The indicators were examined after collecting necessary data using questionnaires for teachers, science lesson observation sheets, and questionnaires for students. The same survey instruments were used during the BLSIA and ELSIA.

11.6 Construction and Administration of Instruments

In view of some common characteristics of SCIB project and the national science curriculum, some measurable parameters (McCormick and James 1983) were identified by an expert committee on the study. Based on these parameters, four questionnaires were constructed for baseline data collection from students, teachers (trained and untrained), principals, and one class observation checklist. The instruments

Table 11.1 Indicators of the impact analysis

Instrument	Indicators		Question/observation point (sub indicators)
	Understanding of the SCIB lesson		What is the most encouraging thing in the new curriculum of general science?
			Do you use lesson plans/teachers guide?
Questionnaire for teachers	Skill for the SCIB lesson		Have you ever made science teaching materials for your own class? (additional)
			(Primary teachers only) most favorite subject area to teach?
	Motivation for the SCIB lesson		(Primary teachers only) least favorite subject area to teach?
			Would you like to keep learning to improve your science teaching skills? (additional)
		Material	Did teacher use: (encircle choices)
			Did students ask question to their teacher?
			How many times?
		Question	How many students?
			Example of question (for possible qualitative analysis) (additional)
Science lesson observation	Quality of science lesson from SCIB perspective	Prediction	Where students given the chance of prediction on any scientific events?
			How many times?
			Example of prediction (for possible qualitative analysis) (additional)
		Discovering	Where students given the chance of discovering on any scientific matters?
			How many times?
			Example of discovering (for possible qualitative analysis) (additional)
		Activity	Which activities of science learning did students experience in the class lesson? (select all)
Questionnaire far students			What subject at school do you like best?
	Interest and motivation		Do you like answering to teacher's question in the science class?
			What question did you ask in today's science class? (yes/no for quantitative survey)
			Is science difficult to understand?

used for this survey were a combination of close-ended and open-ended questions. Three main instruments were constructed using the Likert scale. All the instruments met the basic requirements of face validity and content validity. The reliability coefficient alpha of three instruments was found to be 0.72, 0.69, 0.75, and 0.70, respectively. The instruments were translated into the national language “Urdu” for the convenience of respondents and were pretested before field survey. In each school included and not included in the project, the students’ questionnaires were administrated by the enumerators, teachers’ interviews were conducted by the survey supervisors, and principal’s questionnaires were filled by the assignment manager. The observation sheets were filled in during classroom teaching of lesson plans developed by a team of SCIB project. The same instruments were used for data collection for the end-line survey after 2 years. A statistical computer program was used for the purpose of data tabulation and analysis. The experts interpreted their findings, drew conclusions, and finally made recommendations. The detailed results and analysis carried out by the study team are given in the main study. Only the major findings of the JICA report (JICA 2012) are presented in this paper.

11.6.1 Sampling

The BLSIA and ELSIA were conducted in the same 52 schools consisting of 36 pilot schools and 16 control schools in ICT. On the occasion of BLSIA, 40 sample pilot schools were selected using the following criteria, in order of priority: (a) schools that have both primary (grades 1–5) and elementary (grades 6–8), (b) schools that have primary with higher priority to elementary, and (c) schools that have elementary at least half in each cluster. At the same time, 12 schools were selected as control schools for the analysis. However, four sample schools were excluded from the pilot schools after the BLSIA. The four excluded schools were considered as control schools for the analysis. The questionnaires in the ELSIA were given only to the same teachers and students in the BLSIA for the purpose of using repeated test as part of the analysis. On the other hand, the same number of science lessons was observed during both surveys, complementing lessons of the missing teachers because of the transfer to the other schools or to grades 1–3, etc. The aggregate number of samples is shown in Table 11.2. Grades of the students for analysis were selected considering the schedule of pilot teacher training activities in ICT. Pilot teacher training was conducted in October 2010 for primary school teachers and in October 2011 for elementary school teachers.

Therefore, during BLSIA in 2009, students in grade 3 studied general science with trained teachers for 1 year. At the same time, it was less difficult to trace those students since they possibly continued attending the same primary schools that offered grades 1–5. Grade 5 students in 2009, who were grade 7 in 2011, were selected because their teachers attended the pilot teacher training for elementary level in October 2011. Grade 7 students in 2009 were surveyed for stationary comparison, which is not mentioned here though.

Table 11.2 Number of samples of BLSIA and ELSIA surveys

	BLSIA						ELSIA		
	36 pilot schools		16 control schools		Total (52 schools)				
	Repeated at ELSIA	Only at BLSIA	Repeated ELSIA	Only at BLSIA	Repeated ELSIA	Only at BLSIA	36 pilot schools	16 control schools	Total (52 schools)
Questionnaire for teacher	134	60	58	24	192	84	134	58	192
Science lesson observation	20	40	11	12	31	52	60	23	83
Questionnaire for students	2,460	4,238	798	1,355	3,258	5,593	2,460	798	3,258

11.7 Results of the Analysis

The collected data were categorized into primary and elementary levels due to the length of the teacher's exposure to the project. Moreover, the analysis was realized based on the comparison between trained and untrained teachers for the questionnaire survey for teachers and between pilot and control schools for the lesson study observation and questionnaire survey for students. The following shows an extract of ELSIA and additional analysis using the survey data (JICA 2012).

1. *Whether the project activities improved the understanding, skills, and motivation of teachers on SCIB science lessons*
   Table 11.3 shows the number of samples of the questionnaire survey for teachers.

   (a) "What is the most encouraged thing in the new curriculum of General Science?"
   The question prepared seven options. Among them, the "chances of student explanation to be provided" was expected to be chosen. The ratio of both trained and untrained teachers who chose the expected answer increased in ELSIA as observed in Fig. 11.3, and a statistical examination (difference-in-differences estimation) given in Table 11.4 showed a significant increase of the ratio of trained teachers with expected answer in comparison with untrained teachers ($P<.01$). Therefore, it was concluded that the teacher training implemented by the project improved teachers' understanding.

   (b) "Do you use lesson plans/teacher guide?"
   The ratio of both trained and untrained teachers who used lesson plans/teacher's guide increased in ELSIA as observed in Fig. 11.4. A statistical examination (difference-in-differences estimation) given in Table 11.5 showed a significant increase of the ratio of the trained teachers who used lesson plans/teacher's guide compared with untrained teachers ($P<.01$). Therefore, it was concluded that the project's teacher training made more teachers utilize "tools" to realize SCIB science lessons. Thus, it was concluded that the project activities improved teachers' understanding and skills on SCIB science lessons.

Table 11.3 Number of samples of questionnaire surveys for teachers

	BLSIA				ELSIA			
	36 pilot schools				36 pilot schools			
	Trained	Not trained	16 control schools	Total (52 schools)	Trained	Not trained	16 control schools	Total (52 schools)
Questionnaire for teachers (primary)	20	41	30	91	17	37	21	75
Questionnaire for teachers (elementary)	15	58	28	101	18	62	37	117

Fig. 11.3 Ratio of teachers who committed on the most encouraged thing in the new science curriculum

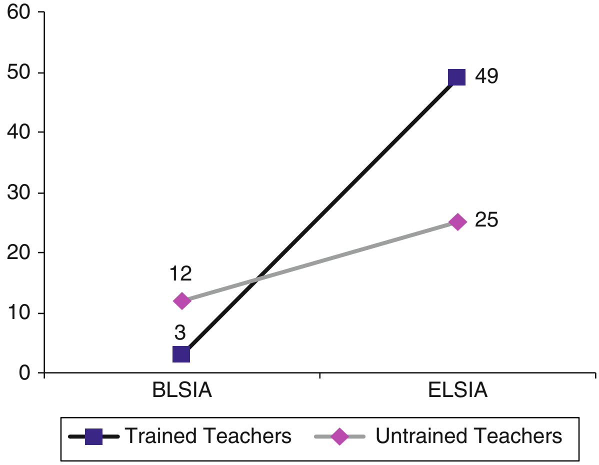


Table 11.4 Statistical examination of trained and untrained teachers on their understanding

		BLSIA trained ($N = 35$)			BLSTA untrained ($N = 157$)		
		Correct	Incorrect	Total	Correct	Incorrect	Total
ELSIA	Correct	0.03	0.46	0.49	0.06	0.19	0.25
	Incorrect	0.00	0.51	0.51	0.06	0.69	0.75
	Total	0.03	0.97	–	0.12	0.88	–
						CR = 3.56 ($P < 0.01$)	

Fig. 11.4 Ratio of teachers who used lesson plan/teacher's guide

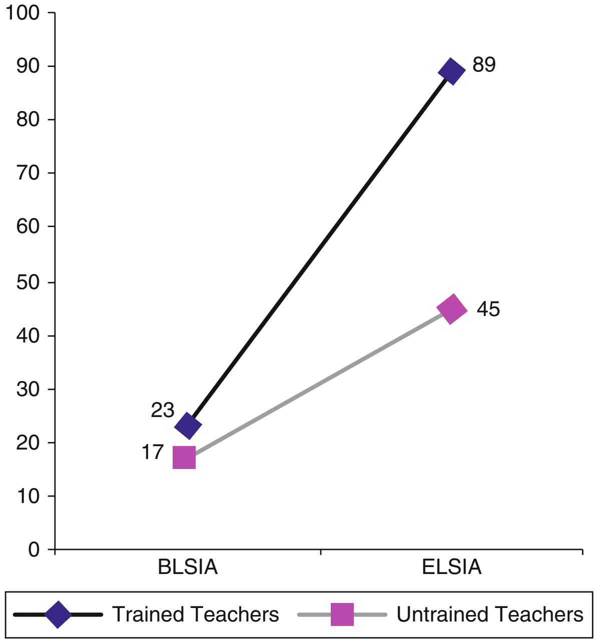


Table 11.5 Statistical examination of trained and untrained teachers on use of lesson plans

		BLSIA trained ($N=35$)			BLSTA untrained ($N=157$)		
		Yes	No	Total	Yes	No	Total
ELSIA	Yes	0.23	0.66	0.89	0.10	0.35	0.45
	No	0.00	0.11	0.11	0.07	0.48	0.55
	Total	0.23	0.77	–	0.17	0.83	–
						CR = 4.10 ($P<0.01$)	

Table 11.6 Number of samples of the lesson plan observation

	BLSIA				ELSIA			
	36 pilot schools		16 control schools	Total (52 schools)	36 pilot schools		16 control schools	Total (52 schools)
	Trained	Untrained			Trained	Untrained		
Science lesson observation (primary)	9	24	13	46	15	18	13	46
Science lesson observation (elementally)	2	25	10	37	5	22	10	37

2. *Whether trained teachers improved the teaching-learning process of science lessons*

   The data were categorized into lessons at pilot schools including both trained and untrained teachers due to the lack of "trained" samples and lessons at control schools. Table 11.6 shows the number of samples of the lesson plan observation.

   (a) *Were "questions by students," "chances of prediction by students," and "chances of discovery by students" observed in the lessons? – change in each aspect between BLSIA and ELSIA.*

   The project considered "questions by students," "chances of prediction on any scientific event by students," and "chances of discovery on any scientific event by students" in the teaching-learning process as indicators of the quality of SCIB science lessons. In pilot schools, every indicator except "questions by students" at primary level showed improvement in ELSIA, but most of them showed no significant improvement. Only "chances of prediction by students" at primary level obtained statistically significant difference between BLSIA and ELSIA ($P<.01$) and between pilot schools and control schools in ELSIA ($P<.05$) of primary and elementary levels. Accordingly, the teaching-learning process of science lessons seemed to be improving in pilot schools for both primary and elementary levels.

   (b) *Were questions by students, "chances of prediction by students, and chances of discovery by students" observed in the lessons? – number of changed aspects*

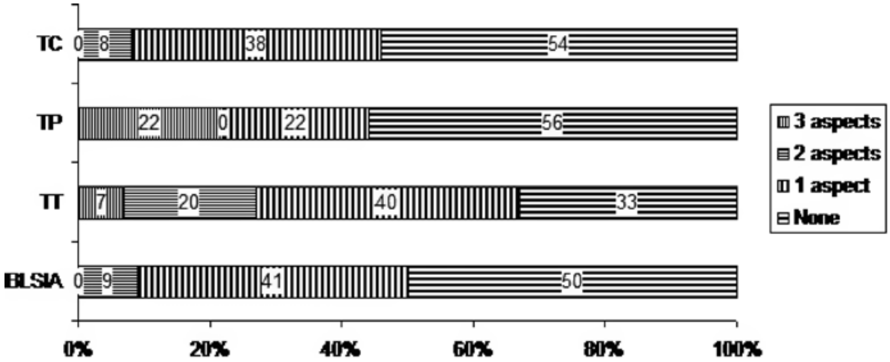


Fig. 11.5 Practice of three aspects in the observed lessons at primary level

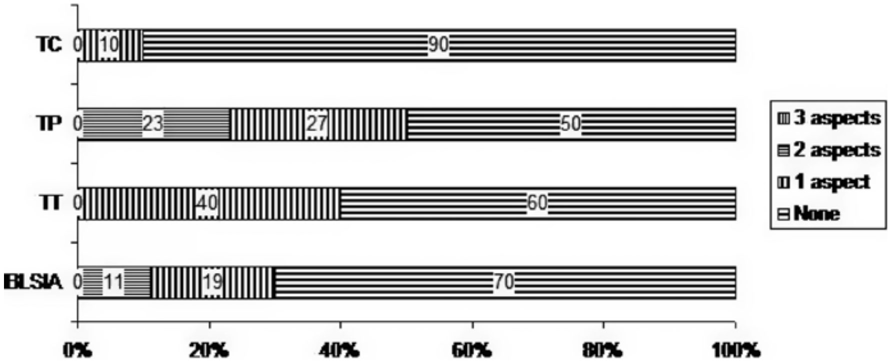


Fig. 11.6 Practice of three aspects in the observed lessons at elementary level

Figures 11.5 and 11.6 show how many of the three aforementioned aspects were practiced in science lessons by trained teachers (TT), untrained teachers in pilot schools (TP), and teachers in control schools (TC) during ELSIA in comparison with BLSIA aggregate data. At primary level, 50 % of the teachers in BLSIA and less than 50 % of both TP and TC practiced at least one aspect in the lesson, whereas 67 % of TT practiced at least one during ELSIA among the 15 primary TT, one (7 %) practiced all the aspects, three (20 %) practiced two aspects, and six teachers (40 %) did one aspect in their science lesson. The results at elementary level did not show a noticeable impact of the training. It should be noted again that the training for elementary teachers was not finished, yet when collecting the data for ELSIA, some factors other than the training impact might be reflected more in the result. The statistical examination was not realized due to the lack of samples.

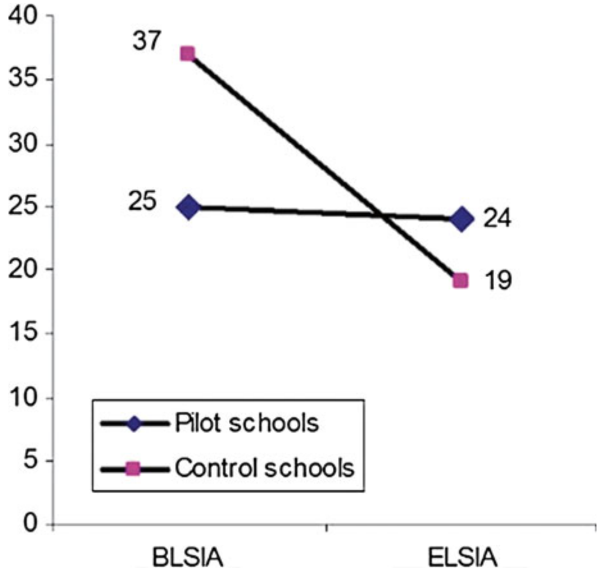


Fig. 11.7 Ratio of students who liked science best at primary level

3. Whether students increased their interest and motivation in pilot schools
   The analysis was realized using the data of students including those who were not promoted or did not respond to the questionnaires repeatedly in BLSIA and ELSIA.

   (a) "What subjects at school do you like best?"
   Figure 11.7 shows that the ratio of students who said "science is the best" decreased in both pilot and control schools at the primary level, i.e., one point decreased in pilot schools and 18 points decreased in control schools. A difference-in-differences estimation given in Table 11.7 showed statistical significance between pilot and control schools. It seemed that students in pilot schools could maintain their interest in science more than those in control schools after being promoted to a higher grade, where the content of the study was generally more complex for students.

   On the other hand, Fig. 11.8 shows that the ratio of students who said "science is the best" increased in both pilot and control schools at elementary level, but there was no statistical significance between the two schools as shown in Table 11.8.

   (b) "Is science difficult to understand?"
   Figure 11.9 shows that the ratio of primary students who said "science is difficult to understand" was 20 % during BLSIA but this decreased to 16 % during ELSIA in pilot schools.

   Meanwhile, the ratio increased from 13 to 25 % at control schools. The statistics estimated the difference to be significant at 1 % level between pilot and control schools as given in Table 11.9.

Fig. 11.8 Ratio of students who liked science best at elementary level

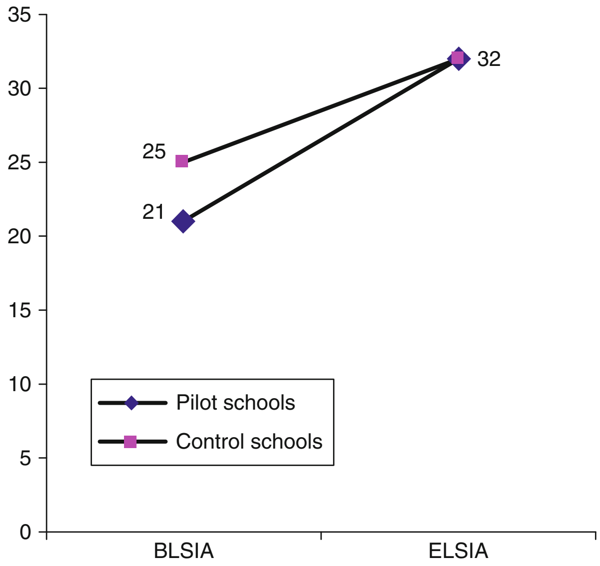


Table 11.7 Statistical examination of "science the best" between pilot and control primary schools

		BLSIA pilot schools ($N=1,592$)			BLSIA control schools ($N=500$)		
		Science	Other	Total	Science	Other	Total
ELSIA	Science	0.07	0.17	0.24	0.08	0.11	0.19
	Other	0.18	0.58	0.76	0.28	0.52	0.81
	Total	0.25	0.75	–	0.37	0.63	–
						CR = 5.48 ($P<0.01$)	

Table 11.8 Statistical examination of "science the best" between pilot and control elementary schools

		BLSIA pilot schools ($N=868$)			BLSIA control schools ($N=298$)		
		Science	Other	Total	Science	Other	Total
ELSIA	Science	0.09	0.22	0.32	0.11	0.20	0.32
	Other	0.12	0.57	0.68	0.14	0.55	0.68
	Total	0.21	0.79	–	0.25	0.75	–
						CR = 1.03 ($P<0.05$)	

It seemed that students in pilot schools had less difficulty in science than those in control schools after being promoted to a higher grade where the content of the study was generally more difficult for students. On the other hand, the ratio of elementary students who said "science is difficult to understand" increased from 18 to 19 % in pilot schools and decreased from 18 to 13 % in control schools. Statistical estimation suggested that the difference was significant at 5 % level as shown in Table 11.10.

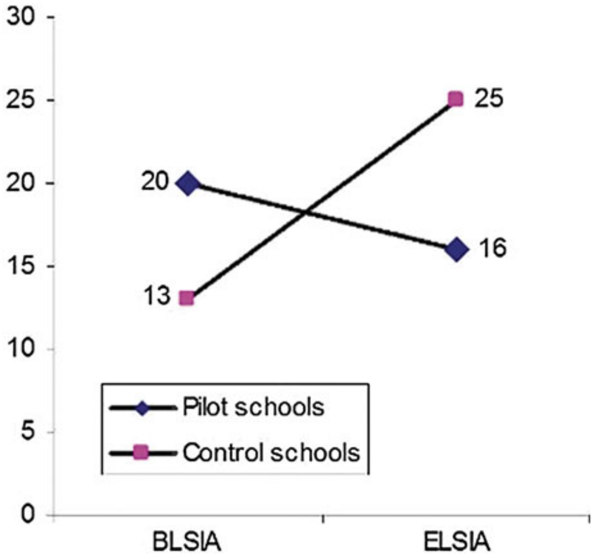


Fig. 11.9 Ratio of students who said science was difficult at primary level

Table 11.9 Statistical examination of "science the difficult" between pilot and control primary schools

		BLSIA pilot schools (N = 1,592)			BLSIA control schools (N = 500)		
		Yes	No	Total	Yes	No	Total
ELSIA	Yes	0.04	0.12	0.16	0.05	0.20	0.25
	No	0.17	0.67	0.84	0.08	0.68	0.75
	Total	0.20	0.80	–	0.13	0.87	–
						CR = 4.54 (P < 0.01)	

Table 11.10 Statistical examination of "science the difficult" between pilot and control elementary schools

		BLSIA pilot schools (N = 868)			BLSIA control schools (N = 298)		
		Yes	No	Total	Yes	No	Total
ELSIA	Yes	0.05	0.14	0.19	0.04	0.09	0.13
	No	0.13	0.68	0.81	0.14	0.72	0.87
	Total	0.18	0.82	–	0.18	0.82	–
						CR = 1.54 (P < 0.05)	

Consequently, it was concluded that students increased their interest and motivation in pilot schools at the primary level. However, no improvement was observed at the elementary level. Instead, one sub-indicator suggested the presence of more motivated students in control schools.

11.8 Conclusions and Discussion

The impact analysis concluded that the teacher training implemented by the project improved the understanding and skills of teachers to realize SCIB science lessons, but the improvement of the teaching-learning process was partial, i.e., only "chances of prediction on any scientific event by students" was increased at the primary level. It was considered as a reflection of the length of exposure of teachers, i.e., teacher training for primary teachers was terminated only 1 year before the ELSIA, and the training program for elementary teachers had not been completed at the time of the survey. As for the project's impact on students, an increase in interest and motivation was observed at the primary level but not at the elementary level. This could be due to (1) the length of teachers' exposure to the project, (2) lack of teachers' experience in lesson study, (3) necessity of higher-grade students to rote and memorize contents because of the nature of the exams, etc. The positive results observed in control schools were considered a product of any elements other than the project activities. The SCIB project met this expectation to some extent, and results of the study show that handsome stakeholders of the in-service teacher training programs of the country have received awareness. The basic purpose of the SCIB project was to conceive a framework of science's teacher training and using this in its true spirit at federal and provincial level in Pakistan. According to Tahir (2011), "the training model that ensures teachers to deliver SCIB science lessons is established – refers training package including training system, method, contents, its effectiveness, challenges and lessons learned derived from the experience in the five clusters in ICT." The end-line survey specifically analyzed the project activities and training program based on (1) questioning from students as well as from teachers, (2) predicting science phenomena and events, and (3) discovering science through activities and projects. However, these surveys did not include the methodology and assessment components of the training imparted to the science teachers. The real test of the material and the model developed under the project will come when this will be disseminated and implemented in the typical schools in the provinces.

11.9 Implications of SCIB Project on Standards of Science Curriculum

The results of impact surveys can be articulated toward quality of science education in Pakistan. It is now desired to expand and develop a regular infrastructure which ensures the sustainability and continuity of efforts for the achievements of benchmarks and standards described in science curriculum. The stakeholders involved in the SCIB project especially the science teachers who received training under the project may play a leading role toward professional development of in-service education of teachers. According to the National Education Census 2005 (govt. of Pakistan), only 60 % of education is covered in the public sector and the remaining

40 % is shared by NGOs and private sector of Pakistan. The SCIB project focused on the government sector, and only a few awareness seminars were organized for others to familiarize with the project activities. As a matter of fact, the standard-based science curriculum is equally applicable for the nonpublic sector. The activities and programs of SCIB project are therefore to be disseminated to the private sector as part of a crash program through training, delivery, and use of lessons and activities. It would be therefore an ideal if the teacher training is imparted by mentors/master trainers providing each union council with a Teacher's Training Center. For the achievement of benchmarks set in new science curriculum (2006), it looks quite appropriate to identify some core professional standards for science teachers as well. The curriculum of teacher education and training has never been remained a part of regular exercise parallel to revision of national curriculum for students in Pakistan. This is perhaps a first attempt to focus on this particular area leading toward quality of science education in Pakistan.

References

American Association for the Advancement of Science. (1990) Science for all Americans, project 2061. Oxford University Press. New York American Association for the Advancement of Science – AAAS (1993) benchmarks for science literacy. New York: Oxford University Press.

American Association for the Advancement of Science. (1993). *Benchmarks for science literacy*. New York: Oxford University Press.

Anderson, R. D., et al. (1982). *Science meta-analysis project: Vol. 1* (Final report). Boulder: Colorado University. ED 223 475.

Avargil, S., Herscoviz, O., & Dori, Y. J. (2012). Teaching thinking skill in context-based learning: Teacher's challenges and assessment knowledge. *Journal Science Education Technology, 21*, 207–225.

Azhar, M. (2010). An overview of teacher education in Pakistan. *Pakistan Journal of Education, 27*, 49–61.

Bhatti, R. A. (2009). Issues of in-service teachers. *NUML Research Magazine, 1*, 24–31.

Dori, Y. J., & Herscovitz, O. (1999). Question-posing capacity as an alternative valuation method: Analysis of an environmental case study. *Journal of Research Technology, 6*, 411–430.

Farooq, R. A. (2006). *Teachers perspectives, elementary education in Pakistan* (pp. 124–167). Islamabad: National Book Foundation.

Government of Pakistan. (1979). *National education policy*. Islamabad: Ministry of Education.

Government of Pakistan. (1992). *National education policy*. Islamabad: Ministry of Education.

Government of Pakistan. (2005). National education census 2005, Manual of instructions for enumerators/supervisors. Ministry of Education, Academy of Educational Planning and Management and Statistics Division, Federal Bureau of Statistics, pp. 53, 90.

Government of Pakistan. (2006). *National curriculum document for general science for grades IV–VIII 2006*. Islamabad: Ministry of Education.

Government of Pakistan. (2009). *National education policy*. Islamabad: Ministry of Education.

Government of Punjab. (1998). *Evaluation of in-service teacher training programs for teachers*. Lahore: Department of Education.

Haddad, W. D. (1985). *Teacher training a review of the world bank experience* (p. 40). Nimeograph World Bank.

Harlen, W. (1990). *In-service for teacher educators: A world-wide view. In improving the quality of the teaching profession*. Singapore: ICET.

Harris, M. M., & Fasano, C. (1988). Towards a policy on continuing professional development of teachers: Australian perspectives. *Journal of Educational Policy, 3*(3), 291–300.
Iqbal, S. (2006). Issues of science curriculum in Pakistan. *Pakistan Journal of Education, 25*(2), 33–40.
Japan International Cooperation Agency. (2009). *Record of discussions on agreement of SCIB Project*. Islamabad: Ministry of Education (unpublished document).
Japan International Cooperation Agency. (2012). *Final report.* Islamabad: Ministry of Education (unpublished document).
Kaberman, Z., & Dori, Y. J. (2009). Question posing, inquiry and modeling skill of chemistry students in the case-based computerized laboratory environment. *International Journal of Science and Mathematics Education, 7*, 597–625.
Krajcik, J., McNeill, K. L., & Reiser, B. J. (2008). Learning-goals-driven design model: Developing curriculum materials that align with national standards and incorporate project-based pedagogy. *Science Education, 92*, 1–32.
McCormick, R., & James, M. (1983). *Curriculum evaluation in schools*. London: Croom Helem.
Mechling, K. R., & Oliver, D. L. (1983). Activities, not textbooks: What research says about science programs. *Principal, 62*(4), 41–43.
National Research Council. (1996). *National science education standards*. http://www.nap.edu/openbook.php?record_4962
Naveed, K. (2010). Teacher's perspectives and professional development. *NUML Research Magazine, 2*, 61–66.
Sadler, T. D., & Zeidler, D. L. (2009). Scientific literacy, PISA and socio-scientific discourse: Assessment for progressive aims of science education. *Journal of Research in Science Teaching, 46*, 909–921.
Shami, P. A. (2010). *Education sector reforms academy of educational planning and management* (p. 40). Islamabad: Ministry of Education.
Shymansky, J. A., et al. (1990). A reassessment of the effects of inquiry-based science curricula of the 60's. *Journal of Research in Science Teaching, 27*(2), 127–144.
Tahir, A. Q. (2005). Evaluation of INSET of elementary science and development of a teaching training model for Pakistan. *Science Education International, 11*(4), 23–29.
Tahir, A. Q. (2011). Developing student centered inquiry based teaching approach at elementary level science in Pakistan – A three years implementation cycle. *Asian Social Science Canadian Center of Science and Education, 7*(8), 241–251.
Ullah, I. (2010). Transferring curriculum standards into practice. *NUML Research Magazine, 2*, 91–99.

Chapter 12
A Long-Term Student Teaching Program in Promoting Practical Knowledge for Preservice Science Teachers

Koichi Furuya

Abstract Five weeks of student teaching is required to obtain a science-teaching certificate for secondary school in Japan. In the United States, Finland, and China, this period is longer. The purpose of this study was to investigate whether long-term student teaching (LTST) was effective in helping preservice teachers (PSTs) to develop practical knowledge required as a science teacher. We conducted a yearlong student teaching program; during this period, PSTs attended several sessions of lesson study on teaching a science lesson. To measure the effectiveness of the LTST program, we compared the practical knowledge of the LTST group to that of the short-term student teaching (STST) group in observing a video of a lesson presented as an example (video case). We examined the online (i.e., thinking aloud) and off-line (i.e., writing a report) responses of PSTs 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. After the PSTs observed a video case, those 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 • Preservice teachers

K. Furuya (✉)
Hokkaido University of Education, Asahikawa City, Japan
e-mail: furuya.koichi@a.hokkyodai.ac.jp

B. Zhang et al. (eds.), *International Conference on Science Education 2012 Proceedings: Science Education: Policies and Social Responsibilities*,
DOI 10.1007/978-3-642-54365-4_12,

12.1 Introduction

With increasing experience in the classroom, teachers develop and extend the practical knowledge they need to teach science. Experienced teachers develop a conceptual framework in which knowledge and beliefs about science, the subject matter, teaching and learning, and students are integrated in a coherent manner (Brickhouse 1990). Duffee and Aikenhead (1992) stated that teachers reacted to teaching situations in a holistic and intuitive manner; in doing so, they showed that the teachers' knowledge comprised characteristics of practical knowledge. Van Driel et al. (2001) summarized early studies and pointed out that teachers' practical knowledge guided their actions in practice; they stated that this could be seen as the core of a teacher's professionalism. They also presented five important features of practical knowledge, namely, action oriented, person and context bound, implicit or tacit, integrated, and that in building practical knowledge, teacher's beliefs play an important role. They also referred to pedagogical content knowledge (PCK), which had been introduced as an element of the knowledge base that plays a crucial role (Shulman 1987). In contrast, other studies had focused on elements of teaching itself, including analysis of lessons, setting goals, and writing lesson plans. Roth et al. (2011) taught in-service teachers and preservice teachers (PSTs) to analyze science lessons based on cases presented in videos, with the purpose of promoting teachers' abilities so that they could expand and strengthen their science classes. In this regard, they focused on two types of PCK, namely, knowledge about creating a coherent science content storyline and that about students' thinking regarding specific science content. For the purposes of our study, we combined the meaning of PCK as mentioned by Van Driel et al. with the more general meaning of the term by Roth et al. (2011). Based on our readings of earlier studies, we define science teachers' practical knowledge as integrated knowledge (mainly consisting of PCK), content knowledge (CK), and pedagogical knowledge (PK) (see Fig. 12.1).

In general, the process of developing a science lesson has three phases: pre-, in-, and post-class. Regarding the passage of time, practical knowledge can be divided into three phases. The practical knowledge required in each phase is different from that required in the others. Therefore, we must view practical knowledge as being not only an integrated type of knowledge composed of PCK, CK, and PC but also something that varies considerably at each phase of the lesson (see Fig. 12.2). Teachers can immediately use practical knowledge in the in-class phase. When

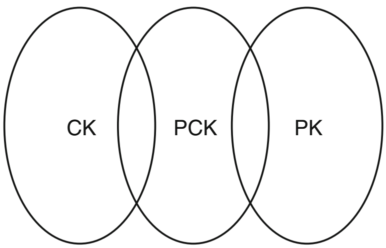


Fig. 12.1 Integrated type of practical knowledge. *CK* content knowledge, *PCK* pedagogical content knowledge, *PK* pedagogical knowledge

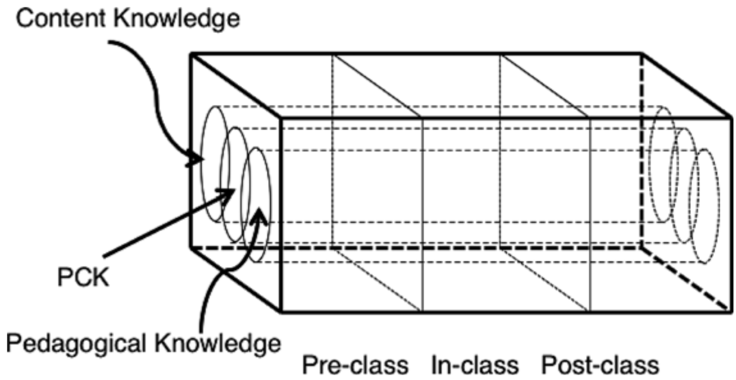


Fig. 12.2 Types of practical knowledge that can be integrated with the flow of time (three phases of class). *CK* content knowledge, *PCK* pedagogical content knowledge, *PK* pedagogical knowledge

teachers capture students' responses and actions, this practical knowledge informs the teachers' decision-making processes. This type of knowledge is required for teachers to respond to students immediately in their own teaching context. This study focuses on the immediate responses that are outgrowths of practical knowledge in the in-class phase. Sato et al. (1991) developed a system that measured expert teachers' online (i.e., thinking aloud) and off-line (i.e., writing a report) responses to analyze their practical thinking style; we use this method in this study.

The purpose of this study was to investigate whether LTST promotes practical knowledge among PSTs. As mentioned earlier herein, practical knowledge has three phases, pre-class, in-class, and post-class. This study focused on the in-class phase, because the teacher who has practical knowledge can capture or monitor students' behaviors and their thinking, making adjustments to his or her instruction based on students' responses. Effective instruction is supported by capturing or monitoring students' responses during the in-class phase. In this present study, we focused on the in-class phase, guided by the following research questions:

1. Are there any differences in practical knowledge between the LTST group, in which PSTs attended STST in their junior year of college and LTST in their senior year of college, and the STST group, in which PSTs only attended STST in their junior year of college?
2. Does the LTST program promote practical knowledge among PSTs?

12.2 Design and Procedure

This section is divided into three parts, namely, the explanation of the LTST program, the explanation of the STST program, and the experimental method of the present study.

All PSTs who obtained a science-teaching certificate at the secondary school level attended STST programs as part of their university training. We recruited six volunteers from among these PSTs; they were divided into two groups, the experimental group and the control group. The PSTs in the experimental group attended the LTST program, and those in the control group did not attend this program. Thus, the experimental group attended STST and LTST training and the control group attended STST training only.

12.2.1 Long-Term Student Teaching: A Yearlong Program

Our research took place at Hokkaido University of Education, Asahikawa City, Japan. In this program, we prepared four course works. The PSTs in the LTST group attended all four course works.

1. Field experience: The PSTs completed 80 h of observation in a 15-week period before LTST started.
2. LTST: This course lasted 40 days in a 10-week period; it took place full time, 4 days per week. During this course, the PSTs participated in lesson studies several times.
3. Student teaching seminar: The PSTs and researchers at the university met every Friday evening to share information and to discuss relevant issues and topics.
4. Inquiry for practical teaching: The PSTs had conducted action research using data that had been collected during LTST. They completed their graduation thesis using these results.

We researchers had a monthly meeting with the PSTs and their cooperating teachers (CTs). We also developed a student teaching journal using a Web-based system to share information with PSTs, CTs, and researchers.

Lesson study is a training method for PSTs to conduct science lessons in real-world situations through writing lesson plans, teaching a lesson, discussing the results with peers and researchers after the lesson, and evaluating and revising the lesson plan. Usually, PSTs are given a week to write a lesson plan before they participate in lesson study.

12.2.2 Short-Term Student Teaching: A Five-Week Program

The STST program contained the following two course works:

1. Guidance before and after student teaching: The PSTs had attended four lectures per day; this program had lasted 4 days and offered guidance to PSTs before their student teaching sessions. This program included student teaching orientation, the observation method for children's behavior, how to write a lesson plan, how to use the blackboard or whiteboard, classroom management, and other topics.

As a means of guidance after their student teaching practice sessions had been completed, the PSTs were divided into small groups to discuss their experiences during the previous 5 weeks.

2. STST: This course lasted 22–24 days in a 5-week period; it took place full time, 5 days per week. During this course, PSTs taught science lessons and underwent a lesson study at least once during 5 weeks of STST.

12.2.3 Procedure

A total of six PSTs participated in this experiment. Three PSTs, who were designated as the subjects, attended the LTST program, and the other three PSTs (i.e., the control group) had attended only the STST training. They were all science education major and were senior students at our university, when these experiments were conducted.

There is not much difference in the academic backgrounds of participants. A science-teaching certificate for secondary school can be obtained in Japan; however, there are no physics-teaching certificate or chemistry-, biology-, or earth science-teaching certificate. A science teacher teaches the domains of physics, chemistry, biology, and earth science in the lower secondary school. On the other hand, although the upper secondary school teachers have science-teaching certificates, they are hired as physics teacher, chemistry teacher, biology teacher or earth science teacher. A total of 85 % of course works about science content is composed of required subjects, with the remaining 15 % being elective. This explains the homogeneity of academic background among participants.

All six participants had attended STST when they were junior student. All of them earned “A” (meaning “excellent”), according to a five-level rating scale.

To investigate the effects of the LTST program, the PSTs in the experimental group and the control group observed a video case of a science lesson. In the video case, a teacher with 10 years of experience gave an earth science lesson to sixth-grade students in a regular classroom setting. Then, we presented the PSTs with the following challenges:

Online (i.e., thinking aloud) monitoring

The PSTs were asked to present their feelings, perceptions, and thoughts by thinking aloud, based on6the case they had observed on the video. Their statements were audio recorded.

Off-line (i.e., writing a report) monitoring

After the previous challenge had been completed, the PSTs were asked to write a report in a journal about their evaluation and impressions of the video case. The reports were turned in to researchers.

After data were collected, audio recordings of PSTs' thinking-aloud sessions were transcribed and were analyzed as follows:

1. The total number of sentences and words of both groups in thinking aloud and writing a report was counted and compared.
2. The contents of the thinking-aloud sessions of the PSTs in the LTST and STST groups were classified and compared qualitatively.
3. The contents of the reports written by PSTs from both groups were analyzed and compared qualitatively.

12.3 Analysis and Findings

12.3.1 Result of Online (Thinking Aloud) Monitoring

The mean number of sentences spoken by the PSTs in the LTST group was 1.7 times greater than that of the STST group. The mean number of words spoken by the PSTs in the LTST group was 2.4 times greater than that of the STST group (Fig. 12.3).

12.3.2 Result of Off-Line (Writing a Report) Monitoring

The mean number of sentences written by the PSTs in LTST group was equal to that written by the STST group. The mean number of words written by the PSTs in LTST group was 1.5 times greater than that written by the STST group; these differences were much less than those discovered in online monitoring (Fig. 12.4).

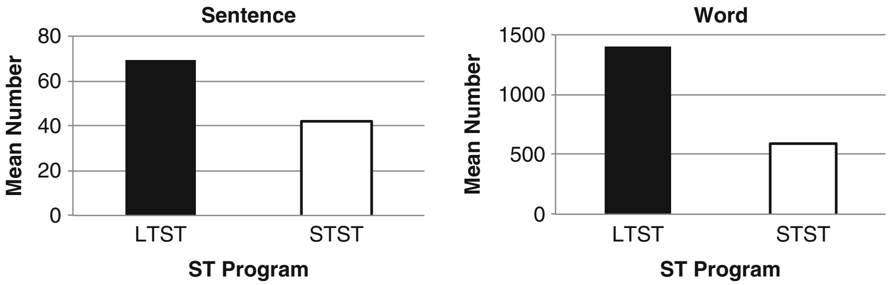


Fig. 12.3 Mean numbers of sentences and words spoken in think-aloud sessions by the LTST and STST groups. *LTST* long-term student teaching, *STST* short-term student teaching

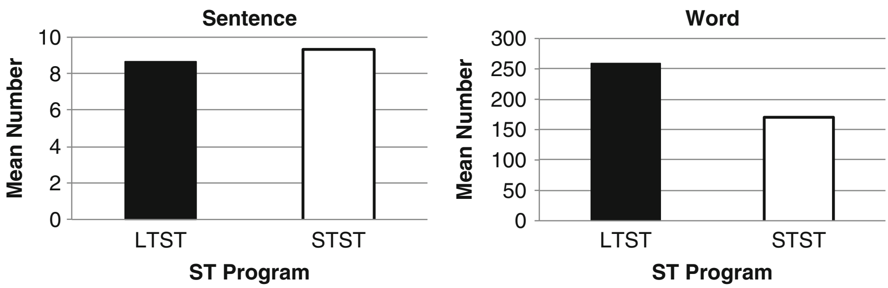
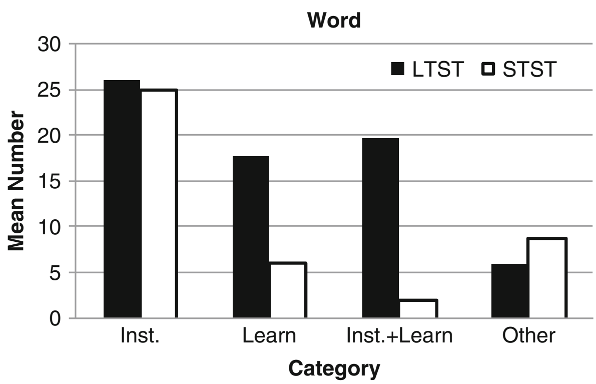


Fig. 12.4 Mean numbers of sentences and words spoken in written reports submitted by the LTST and STST groups. *LTST* long-term student teaching, *STST* short-term student teaching

Fig. 12.5 Classifications of statements made during thinking-aloud sessions by the LTST and STST groups. *LTST* long-term student teaching, *STST* short-term student teaching, *Inst.* instruction, *Learn* learning, *Inst.* + *Learn.* instruction and learning



When observing the lesson, the mean number of sentences and words written by the PSTs in the LTST group was greater than in the STST group. However, after observing the video case, the number of statements given by the LTST and STST groups was almost the same.

12.3.3 Classification of Online (Thinking Aloud) Monitoring

The transcriptions of online monitoring were classified. The criteria were as follows: instruction, focus on the teacher's behavior, particularly regarding teaching; learning, focus on children's learning; instruction and learning, focus on the teacher's behavior and students' responses to it; and others (Fig. 12.5).

The differences in the thinking-aloud results between the LTST and STST groups occurred in the learning category (Learn) and the instruction-and-learning category (Inst. + Learn). Little difference was observed between the groups in the numbers of sentences about instruction category (Inst.). Although the PSTs in the STST group did not focus on the learning category and the instruction-and-learning category, the PSTs in the LTST group frequently spoke about learning as well as about learning and instruction.

12.3.4 Analysis of the Contents of Written Reports from Both Groups

No quantitative differences of description were observed in the written reports; thus, we next analyzed their descriptions qualitatively. The PSTs from the LTST group illustrated the strengths and weaknesses of the lesson of the video case from the viewpoint of a storyline, which focused on connections made between the opening question, the scientific ideas conveyed, the activities undertaken by students, the follow-up discussions based on those activities, and the ending of the lesson depicted in the video case. These PSTs in the LTST also focused on the children's motivation and responses to the teacher's activities. In contrast, the PSTs in the STST group described the lesson in fragments, conveying no sense of the flow of time.

12.4 Conclusions

From our analysis and comparison of practical knowledge, particularly the immediate responses in the thinking-aloud sessions and written reports of the in-class phase by the PSTs in the LTST and STST groups, the following points were revealed:

1. The descriptions spoken during the thinking-aloud sessions by PSTs from the LTST group were 2.4 times more numerous than those spoken by the STST group. According to the early studies mentioned herein, one of the prominent features of practical knowledge, which is possessed by expert teachers, is immediate responsiveness to their students (Sato et al. 1991; Van Driel et al. 2001). This result showed us that, in this respect, the PSTs in the LTST group possessed a greater amount of practical knowledge than their counterparts in the STST group.
2. We classified the descriptions of statements spoken in the thinking-aloud sessions into four categories, namely, instruction, learning, instruction and learning, and others. Although no great distinction was observed in the category of instruction between the LTST and STST groups, the PSTs in the former group spoke 4.6 times more words compared with the latter group in the category of learning and the category of instruction and learning. Expert teachers appreciate children's learning and their changing actions from moment to moment during a lesson (Sato et al. 1991). This practical knowledge, or PCK, corresponds to the student thinking lens mentioned by Roth et al. (2011). Based on this framework, the PSTs in the LTST group had greater practical knowledge than their counterparts in the STST group.

3. Although we observed no major quantitative differences in the written reports, qualitative differences were revealed. The PSTs in the LTST group tended to view the lesson as a storyline (this is an important aspect of PCK) and to analyze it by placing the events of the lesson into a coherent storyline. They had a tendency to focus on the teacher's behavior and children's learning in each stage of the class. By contrast, the STST group lacked this element of PCK: they described events that had impressed them randomly and in a manner that did not take into account the flow of time. Expert teachers think and act in ways that depend on the context of the particular class and the learning taking place (Sato et al. 1991); the conceptual emergence of storyline-based thinking could be seen only among the LTST group.
4. The practical knowledge measured in this study concerned the immediate responses of PSTs in an in-class phase. When conducting science classes, the immediate response of the teacher based on his or her practical knowledge is highly important. As a result, it was revealed that LTST is an effective means of promoting practical knowledge in an in-class context among PSTs.

The significance of this study is as follows. A much greater amount of student behavior and thinking was captured and monitored by PSTs in the LTST group, compared with the PSTs in the STST group. Therefore, it was revealed that the LTST program promoted practical knowledge among PSTs during the in-class phase. Also, the LTST program was effective in helping PSTs to view lessons as storylines. LTST could be used elsewhere to promote this practical knowledge among PSTs.

Acknowledgments This work was supported by JSPS KAKENHI (Grants-in-Aid for Scientific Research [B]) Grant Number 22300267.

References

Brickhouse, N. W. (1990). Teachers' beliefs about the nature of science and their relationship to classroom practice. *Journal of Teacher Education, 41*(3), 53–62.

Duffee, L., & Aikenhead, G. (1992). Curriculum change, student evaluation, and teacher practical knowledge. *Science Education, 76*(5), 493–506.

Roth, K. J., Garnier, H. E., Chen, C., Lemmens, M., Schwille, K., & Wickler, N. I. Z. (2011). Videobased lesson analysis: Effective science PD for teacher and student learning. *Journal of Research in Science Teaching, 48*(2), 117–148.

Sato, M., Iwakawa, N., & Akita, K. (1991). Practical thinking styles of teachers: Comparing experts' monitoring processes with novices. *Bulletin of the Faculty of Education the University of Tokyo, 30*, 177–198.

Shulman, L. S. (1987). Knowledge and teaching: Foundations of the new reform. *Harvard Educational Review, 57*(1), 1–22.

Van Driel, J. H., Beijaard, D., & Verloop, N. (2001). Professional development and reform in science education: The role of teachers' practical knowledge. *Journal of Research in Science Teaching, 38*(2), 137–158.

Chapter 13
Suggesting a Flow Map of the Nature of Science for Sciences Education

Jun-Young Oh

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. Thus, it is valuable to introduce students at the elementary level to some of the ideas developed by Kuhn. Key aspects of the nature of science (see Lederman et al. 2002) are in fact good applications to the history of science through Kuhn's philosophy. Therefore, an NOS flow map could be a promising means of understanding the NOS tenets and an explicit and reflective tool for science teachers to enhance scientific teaching and learning. In the present study, I suggest that we should include instruction about HPS in our science teachers' programs.

Keywords History of science • Nature of science • Science content knowledge • Philosophy of science • Kuhn's philosophy • Copernicus revolution

13.1 Introduction

It is commonly believed that the ultimate aim of science is to discover truths about the external world. The results of scientists' work are exposed to public scrutiny, and this examination and criticism further ensure the objectivity and accuracy of science (Kuhn 1970, p. 55). Thus, science education has concentrated on the knowledge of science content rather than on the process of scientific inquiry.

J.-Y. Oh (✉)
Hanyang University, Seoul 133-791, Republic of Korea
e-mail: jyoh3324@hanyang.ac.kr

B. Zhang et al. (eds.), *International Conference on Science Education 2012 Proceedings: Science Education: Policies and Social Responsibilities*,
DOI 10.1007/978-3-642-54365-4_13,

Shamos (1995) argues that while knowledge of science content may not be necessary for obtaining science literacy, understanding the nature of science is a prerequisite to such literacy. Scientific literacy also includes understanding the nature of science, the scientific enterprise, and the role of science in society and personal life (NRC 1996, p. 21). However, Brush (1989) noted that science teachers are not generally aware of the social and cultural construction of scientific thought.

Brown et al. (2005) has proposed scientific literacy as the following:

> Two central perspectives emerge out of this discussion of scientific literacy. First, Scientific literacy is defined in terms of the knowledge and understanding of scientific concepts and processes required for personal decision making, participation in civic and cultural affairs, and economic productivity. A second perspective seeks to situate any definition of scientific literacy in the actions of accomplishing everyday life. (p. 780)

Here, we argue that scientific literacy should be considered as more expansive, including technical, social, and cultural elements, emphasizing that scientific literacy involves not only the utilizing of science content knowledge (SCK) but also the key aspects of the NOS, both explicitly and reflectively.

In science education, Kuhnian themes are especially noticeable in conceptual change research, constructivist theorizing, and multicultural educational debates (Matthews 2002). Therefore, this study will consider why the nature of science has reached the philosophy of Kuhn and will identify the stage that Copernicus Revolution can take the key elements of the nature of science. Therefore, 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 their overall scientific literacy through explicitness and reflectiveness.

More specifically, the work aims to investigate the following *research questions*:

First, what is the dynamic relation between elements of the nature of science?

Second, what are the elements of a new flow map based on aspects of the nature of science (NOS) and Kuhn's scientific revolution in order to enhance their overall explicitness and reflectiveness?

Third, what are the instruction sequence of the flow map of NOS as a cognitive learning outcome and preservice teachers' views about using the flow map of NOS among science teachers' "desired" understanding of NOS?

Finally, what are the implications for science education, based on the science of history for the nature of science?

13.2 A New Flow Map: Key Elements Based on Aspects of the Nature of Science (NOS) and Kuhn's Philosophy of Science

A philosophical debate about realism (Eflin et al. 1999) and strong social constructivism (Matthews 1994) should be avoided. The intermediate road approach that we offer here seems to be suggested by certain NOS tenets cited by the American Association for the Advancement of Science (AAAS 1993).

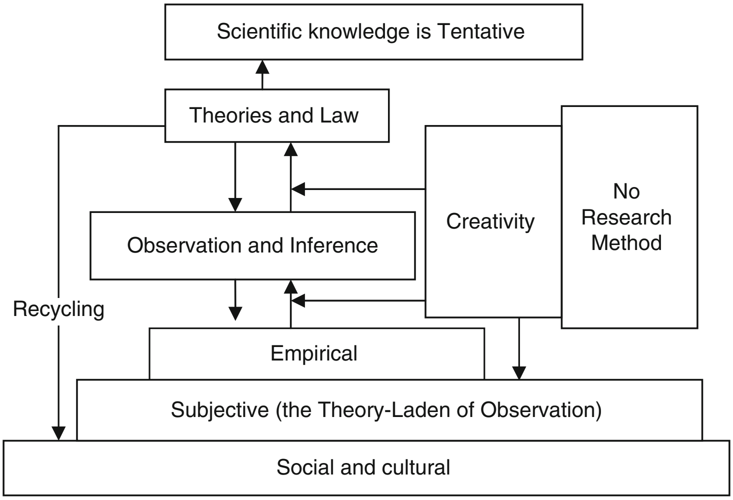


Fig. 13.1 A new flow map based on the key aspects of the nature of science (NOS)

Despite continuing disagreements regarding the specific definition of the NOS, at a certain level of generality and within a certain period of time, there is a "shared wisdom" about the NOS. Lederman (2007) has proposed the following:

> Seven key aspects of NOS: Scientific knowledge is **tentative** (subject to change), **empirically** based (based on and/or derived from observations of the natural world), and **subjective** (involves the personal background, biases, and/or is **theory-laden**); necessary involves human inference, imagination, and **creativity** (involves the invention of explanations); and is **socially and cultural** embedded. Two additional important aspects are the distinction between **observation and inferences**, and the functions of and relationships **between theories and laws**. (p. 53)

We insist that none of these aspects should be considered apart from the others. Thus, these key aspects of the NOS should be viewed in this study as interdependent, dynamic, explicit, and reflective (see Fig. 13.1). Empiricists argue that our perception provides us with objective facts about the world, with the foundations of science and general laws and theories inductively generated based on those facts. However, our perception is not objective. *Judgments and inferences on observable facts* in a special situation will change depending on the individual if the individual is changed, depending on the culture if the culture is changed, or depending on the school if the theoretical school is changed. That is, in the *social and cultural background* where they belong, our perception is formed and developed in a decisive manner by the *subjectivity of an observer* and the cultural and theoretical background, expectations, and perspectives that the observer has. Such a consideration is handled under the title of *the theory-laden of observation* in the philosophy of science. Thus, we insist that a *law* showing regularity and a *theory requiring our creativity* should be dynamic rather than separated, due to the theory-laden of observation. That is, they are not *scientific methods* represented by induction.

Finally, that objective law or theory is not produced from objective facts means that a scientific theory is indeed *tentative*.

For example, the tentativeness of scientific knowledge stems from the creation of that knowledge by empirical observation and inference. Each of these acts is influenced by the culture and society in which the science is practiced as well as by the theoretical framework and personal subjectivity of the scientist. As new data are considered and the existing data are reconsidered, inferences may lead to changes in the existing scientific knowledge (see Fig. 13.1).

Because the flow map that we developed is very closely connected to Kuhn's scientific revolution, we must discuss the relationship between our flow map involving the elements of the NOS (see Lederman et al. 2002) and Kuhn's philosophy.

13.3 The Flow Map of the NOS Through the Prerequisite of Kuhn's Scientific Revolution and the Key Aspects of the NOS

13.3.1 The Crisis of a Normal Science Due to the Number of Serious Anomalies

Socially and Culturally Embedded Scientific Knowledge and the Crisis of Kuhn's Normal Science: Science, as a human enterprise, is practiced in the context of a larger culture, and science's practitioners are the product of that culture. Science, it follows, affects and is affected by the various elements and intellectual spheres of the culture in which science is embedded (Lederman et al. 2002). Therefore, anomalies are regarded as serious if those irregularities are important with respect to a pressing social need. The seriousness of an anomaly is also dictated by the length of time that the anomaly resists removal (Chalmers 1999, p. 113).

13.3.2 The Depth of the Seriousness of a Crisis Due to the Appearance of an Alternative

Subjective: The theory-laden nature of observations about scientific knowledge and the depth of the seriousness of Kuhn's normal science crisis.

Observations and investigations are always motivated and guided by and acquire meaning in reference to questions or problems, which are derived from certain theoretical perspectives (Lederman et al. 2002). According to Kuhn, a new paradigm, or a hint sufficient to permit later articulation, emerges all at once, occasionally in the middle of the night, in the mind of an individual deeply immersed in a crisis (Chalmers 1999, p. 114).

13.3.3 The Completion of the Revolution by the Disciplinary Successors of a New Paradigm

Through the continuous studies of disciplinary successors, additional empirical observations accumulation for resolving serious anomalies, and these anomalies and new observations and inferences to explain them, and a new laws and theories turn out. All inquiry procedures are generated via an individual or small community's creativity rather than via data accumulation, an inductive process involving the following elements of the NOS.

Observations are descriptive statements about natural phenomena that are directly accessible to the senses or extensions of the senses and about which observers can reach a consensus with relative ease. In contrast, *inferences* are statements about phenomena that are not directly accessible to the senses (Hull 1998, p. 146).

Scientists derive specific testable predictions from theories and check them against tangible data. Closely related to the distinction between observations and inferences is the difference between scientific theories and laws. In general, laws are descriptive statements of the relationships between observable phenomena. We insist that a *law* showing regularity and a *theory requiring our creativity* should be dynamic rather than separated due to the theory-laden of observation. The acquisition of scientific knowledge involves observing nature. Nonetheless, generating scientific knowledge also involves human imagination and creativity. *Creativity* is necessary in all inquiry, based on all of the key aspects of the NOS.

One of the most widely held misconceptions about science is the existence of the scientific method. There is *no single scientific method* that would guarantee the attainment of infallible knowledge (AAAS 1993; NRC 1996).

13.3.4 A New Stage of Normal Science and Its Recycling (Expansion)

After the completion of the scientific revolution by disciplinary successors, a new paradigm emerges. Scientific knowledge, although reliable and durable, is never absolute or certain. This knowledge, including facts, theories, and laws, is subject to change.

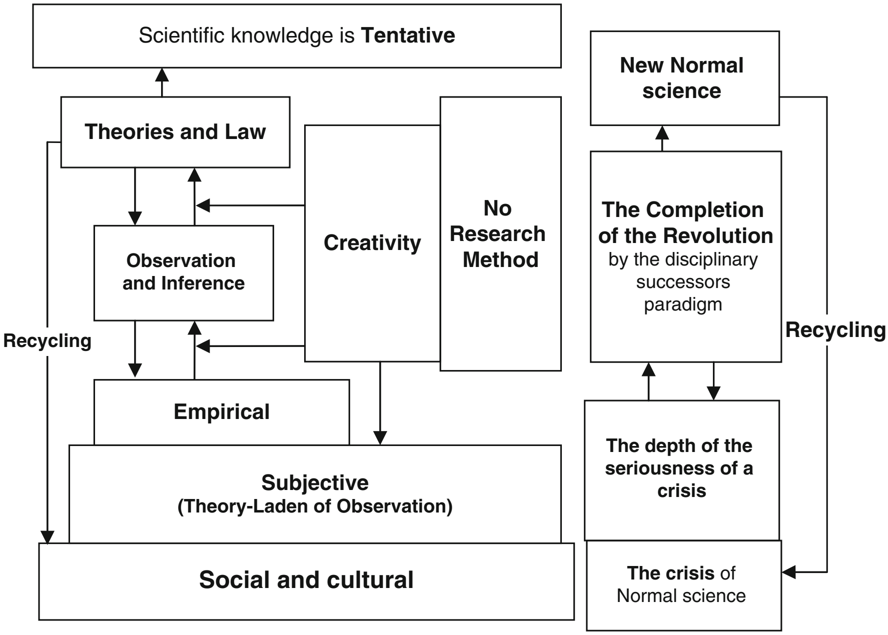


Fig. 13.2 Relationship between the NOS and Kuhn's scientific revolution

More specifically, scientific claims evolve as new evidence, made possible by advances in thinking and technology is presented and as extant evidence is reinterpreted in light of new theoretical advances, changes in the cultural and social spheres, or shifts in the direction of established research programs. Tentativeness in science does not solely arise from the fact that scientific knowledge is inferential, creative, and socially and culturally embedded (see Fig. 13.2).

13.4 Historical Case Studies: The Flow Map of the NOS for the Establishment of Copernicus's Heliocentric Hypothesis

13.4.1 A Crisis Due to the Number of Serious Anomalies: The Crisis of Ptolemy's Geocentric System

For some time, astronomers had every reason to suppose that these attempts would be as successful as those that had led to Ptolemy's system. Astronomers were invariably able to eliminate a given discrepancy by making an adjustment in Ptolemy's system of compounded circles.

13.4.2 The Depth of the Seriousness of a Crisis, Due to the Appearance of an Alternative: The Appearance of Copernicus's System, an Alternative to Ptolemy's System

After repeatedly looking through old data and thinking for a long time, Copernicus concluded that placing the Sun in the center of the universe would allow for a simpler depiction of planetary motion. Upon consideration, where else would be a better place for the Sun that illuminates the universe than the universe's center? He was not the first to claim heliocentric theory. In fact, 2000 years before, Aristarchus (B.C. 310–230) had also claimed heliocentric theory, but he had been completely forgotten.

13.4.3 The Completion of the Revolution by the Disciplinary Successors of a New Paradigm

A number of mathematically capable natural philosophers (Galileo, Kepler, and Newton) were attracted to the Copernican system. With Kepler, the Copernican Revolution was nearly "complete"; Kuhn finds the revolution's completion in Newton's system (Sharrock and Read 2002, p. 79).

13.4.4 A New Stage of Normal Science and Its Recycling: The Expansion of Normal Science

> Galileo and Kepler certainly strengthened the case in favor of the Copernican theory. However, more developments were necessary before that theory was securely based on a comprehensive physics. Newton was able to take advantage of the work of Galileo, Kepler and others to construct that comprehensive physics. Once Newton's physics had been constituted, it was possible to apply it in detail to astronomy, fluid mechanisms and other domains. (Chalmers 1982, p. 74)

13.4.5 Recycling: Retreating or Revising Newton's Theory

Astronomers have long known that the major axis of Mercury's orbit does not remain fixed in space in relation to the stars. General relativity predicts motion due to the strong curvature of space-time close to the sun. The observed and predicted results thus agree within a few percent. Again, observations *confirm* general relativity.

13.5 The Use of NOS Flow Maps

Figures 13.2 and 13.3 show an example of using the flow map of NOS and a complete model of the instruction sequences for the natural sciences from top to bottom. However, the instruction sequences are dynamic rather than static.

According to Matthews (2002), one of the most influential articles in conceptual change research is by George Posner and colleagues' "Accommodation of a Scientific

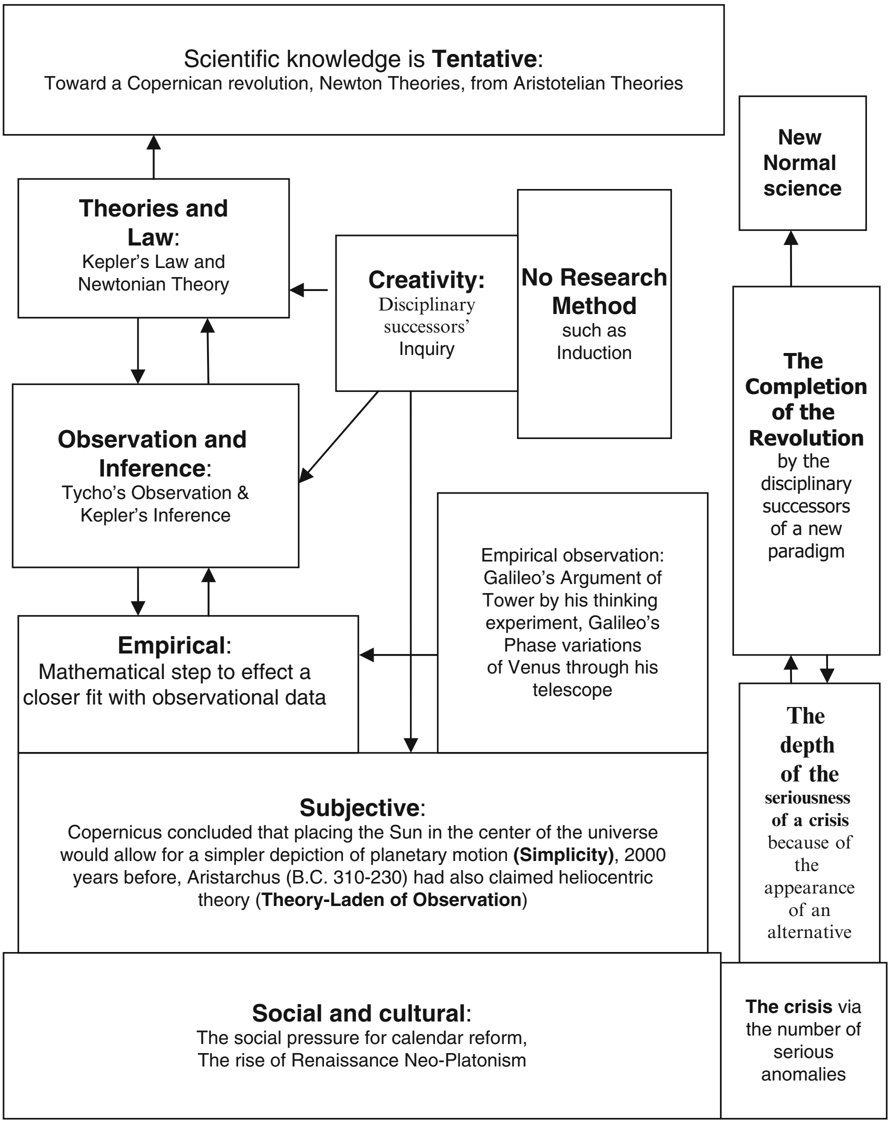


Fig. 13.3 The Copernican revolution: the flow map of the nature of science (NOS)

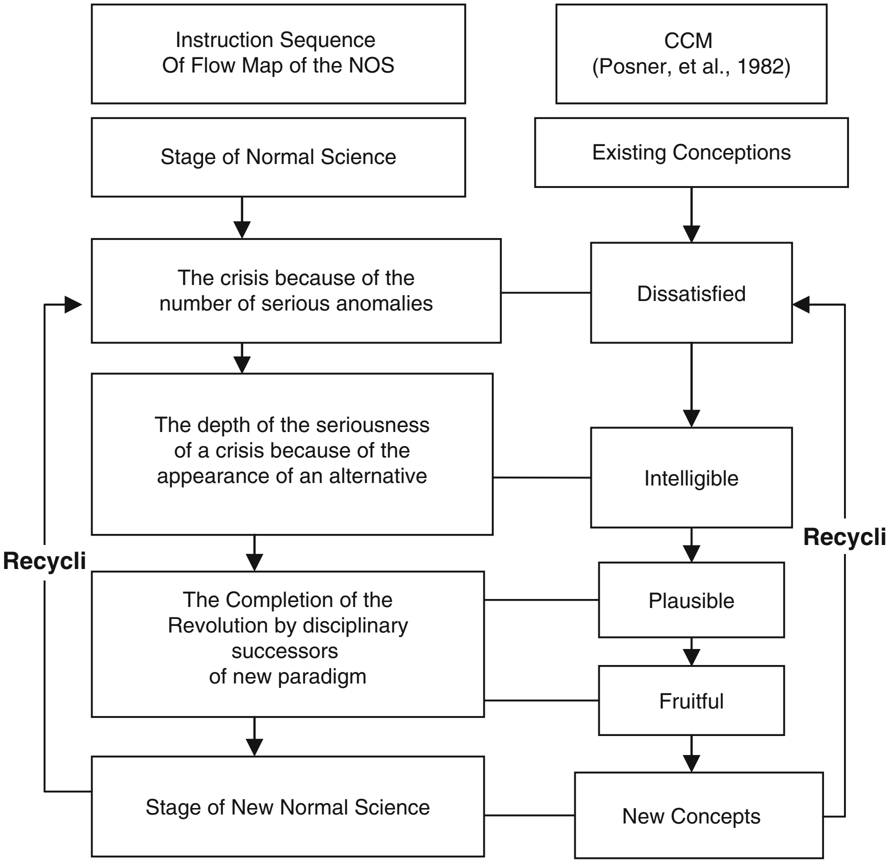


Fig. 13.4 Relations between NOS flow map instruction sequence and conceptual change model

Conception: Toward a Theory of Conceptual Change." It is explicitly based on Kuhn's analysis of paradigm change in science (Posner et al. 1982). Figure 13.4 indicates the NOS flow map, conditions of conceptual change of Posner et al. (1982). The flowchart consists of the criterion taxonomy of the types of cognitive learning outcomes that students achieve after experiencing our suggested teaching and learning program.

13.6 Preservice Teachers' Views About Using NOS Flow Map

Many researchers emphasize that explicitness and reflectiveness should aim to develop teachers' concepts of the NOS, as "despite the relative 'effectiveness' of the explicit approach, much is still required in terms of fostering among science teachers 'desired' understandings of NOS" (Akerson and Abd-El-Khalick 2003).

Thus, we first established preservice elementary school teachers' views about the use of NOS flow maps.

13.6.1 Participants and Methods

Seventy-eight preservice elementary school teachers completed a questionnaire. These teachers were enrolled in courses as part of the literacy program at the J. National University of Education of South Korea. Before answering the questionnaire, all of these teachers were instructed in the theory of constructivism.

13.6.2 Results and Discussion

The results of the questionnaire are presented in Table 13.1. Most of the surveyed preservice elementary school teachers liked the idea of using NOS flow maps (item 1) and agreed that the process of developing NOS flow maps helped in the design of better instructional plans about the NOS (items 2, 3). Many of the teachers believed that using NOS flow maps in science instruction could aid cognitive learning (item 9). The effectiveness of using NOS flow maps was also appreciated by most of the teachers (item 4). Additionally, the surveyed group presumed that current preservice elementary school teachers would like the idea of using NOS flow maps. However, many of the surveyed teachers deemed the construction of NOS flow maps a difficult process (item 5). Therefore, we recommend that teachers collaborate with one another to develop appropriate NOS flow maps for students and teachers (see Table 13.1).

13.7 Discussion and Conclusion

In recent science education reform-related documents, aspects of the NOS have been emphasized as disagreeing with the received views of common science (AAAS 1993; NRC 1996). Scientific knowledge is tentative; empirical; theory-laden; the product of human inference, imagination, and creativity; and socially and culturally embedded. Three additional important aspects of scientific knowledge are the distinction between observation and inference, the lack of a universal method for conducting scientific research, and the functions of and relationships between scientific theories and laws.

It is valuable to introduce students at the elementary level to some of the ideas developed by Kuhn (Eflin et al. 1999). Thus, the development of flow map for the key aspects of the nature of science is a good case to Copernicus Revolution, one of the main accidents of the history of astronomical science as the historical case studies.

Table 13.1 Preservice elementary school teachers' views about using the NOS flow maps

Question	Strongly agree *N* (%)	Agree *N* (%)	Neutral *N* (%)	Disagree *N* (%)	Strongly disagree *N* (%)	Sum *N* (%)
1. I like the idea of using an NOS flow map	15 (19)	52 (67)	9 (12)	2 (2)		78 (100 %)
2. The process of constructing an NOS flow map furthers my understanding of aspects of the NOS	13 (17)	51 (65)	13 (17)	1 (1)		78 (100)
3. The process of developing an NOS flow map gives me a more integrated view of the scientific knowledge that will be taught	16 (20)	52 (67)	10 (13)			78 (100)
4. Compared with traditional teaching methods, the use of an NOS flow map is expected to achieve better learning outcomes for my students	17 (22)	50 (64)	9 (12)	2 (2)		78 (100)
5. The construction of an NOS flow map is an easy process	3 (4)	14 (18)	31 (40)	27 (34)	3 (4)	78 (100)
6. I am eager to view other teachers' NOS flow maps	9 (12)	51 (65)	17 (22)	1 (1)		78 (100)
7. I am eager to explore whether an NOS flow map is useful for the students and teachers	23 (30)	43 (55)	12 (15)			78(100)
8. In order to construct an NOS flow map, I have read some other relevant literature	11 (14)	47 (61)	19 (24)	1 (1)		78 (100)
9. I believe that the use of an NOS flow map could be applied to various aspects of science instruction	16 (21)	44 (56)	18 (23)			78 (100)

In our flow map including NOS, HOS, SCK, and POS, their instructional sequence was suggested from bottom to top. We present a strategy to begin from the most important core aspects of NOS and then introduce supportive scientific contents knowledge (SCK) and history of science (HOS) to explain the cores as a cognitive learning outcome explicitly and reflectively, in order for teachers to help students reconstruct alternative concepts based on new scientific knowledge.

However, preservice teachers responded that although it is necessary to employ such strategies, it is actually difficult to develop such a sequence. Therefore, it is necessary to develop NOS flow maps and strategies that are easy to follow and are widely applicable.

Finally, we conclude that the NOS dichotomy is misleading. Instead of being mutually exclusive, the NOS, HOS, SCK, and POS could complement each other.

We should teach about HPS in our science teachers' training programs. Knowledge of HPS for the nature of science can be at least as useful to students and working scientists. Although the present study did not demonstrate that HOS plays a dual role, significantly increasing students' scores in both the NOS and SCK, it is apparent that the HOS provides instructional resources for scientific teaching if this history is explicitly contextualized into domain-specific content. A science teacher must also bring to the classroom the attitude and world view of scientists, as only experiencing the scientific process is not sufficient for students. To achieve this objective, a basic understanding of Kuhn's philosophy of science is necessary.

There is a main limitation to the present investigation. Learning and teaching outcomes related to scientific inquiry and teaching of a flow map of NOS were not presented in preservice teachers. Formal assessment of the effects of a flow map of the NOS on these learning outcomes will be necessary in the future.

References

Akerson, V. L., & Abd-El-Khalick, F. S. (2003). Teaching elements of nature of science: Yearlong case study of a fourth grade teacher. *Journal of Research in Science Teaching, 40*, 1025–1049.

American Association for the Advancement of Science (AAAS). (1993). *Benchmarks for science literacy*. New York: Oxford University Press.

Brown, B., Reveles, J., & Kelly, G. (2005). Scientific literacy and discursive identity: A theoretical framework for understanding science learning. *Science Education, 89*, 779–802.

Brush, S. G. (1989). History of science and science education. *Interchange, 20*, 60–71.

Chalmers, A. F. (1982). *What is this thing called science?* (2nd ed.). St Lucia: University of Queensland Press.

Chalmers, A. F. (1999). *What is this thing called science?* (3rd ed.). Cambridge: Hackett Publishing, Inc.

Eflin, J. T., Glennan, S., & Reisch, G. (1999). The nature of science: A perspective from the philosophy of science. *Journal of Research in Science Teaching, 36*(1), 107–116.

Hull, D. L. (1998). *Science as a process: an evolutionary account of the social and conceptual development of science*. Chicago: University of Chicago Press.

Kuhn, T. S. (1970). *The structure of scientific revolution* (2nd ed.). Chicago: The University of Chicago Press.

Lederman, N. G. (2007). Nature of science: Past, present, and future. In S. Avell & N. Lecerman (Eds.), *Handbook of research on science education*. Mahwah: Lawrence Erlbaum Associates Publishers.

Lederman, N. G., Abd-El-Khalick, F., Bell, R. L., & Schwartz, R. S. (2002). Views of NOS questionnaire toward valid and meaningful assessment of learners' conceptions of NOS. *Journal of Research in Science Teaching, 39*, 497–521.

Matthews, M. (1994). *Science teaching: The role of history and philosophy of science*. New York: Routledge.

Matthews, M. (2002). Thomas Kuhn's impact on science education: What lessons can be learned? *Science Education, 88*, 90–118.

National Research Council (NRC). (1996). *National science education standards*. Washington, DC: National Academic Press.

Posner, G., Strike, K. A., Hewson, P. W., & Gertzog, W. A. (1982). Accommodation of a scientific conception: Toward a theory of conceptual change. *Science Education, 66*(2), 211–277.

Shamos, M. (1995). *The myth of scientific literacy*. New Brunswick: Rutgers University Press.

Sharrock, W., & Read, R. (2002). *KUHN: Philosopher of scientific revolution*. Malden: Polity Press c/o Blackwell Publishing Ltd.

Part IV
Other Topics

Chapter 14
Relationship Between Learning Quality and Learning Approaches of High School Students on the Subject of Chemistry

Li-Hua Zou, Jia Li, Wen-Chu Chen, Ming-Li Zhong, and Zhao-Yang Wang

Abstract Students' learning approaches and teachers' teaching styles have significant impacts on students' learning quality. It is important to study the relationship between students' learning quality and learning approaches. In this research study, the students' learning quality is defined by the SOLO (Structure of the Observed Learning Outcome) of students' learning results; and learning approaches are categorized into surface level, deep level, and achievement level. Students from selected high schools participated in the study. Data on students' learning approaches were obtained through a survey using the "Students Learning Process Questionnaire." After the survey, the SOLO tests on high school "chemistry reaction principles" were given to the same students. Correlation analysis were conducted to find out the relations between student learning approaches and learning quality. It was found that most students use deep- and achievement-level learning approaches; much fewer students use the surface-level learning approach. Statistically, student learning quality was significantly correlated with achievement- and deep-level learning approaches. Students at higher levels of SOLO structure tend to adopt deep-level learning approaches. From these results, we recommend that during teaching, it is effective for teachers to guide students toward deep- and achievement-level learning approaches.

Keywords Chemistry for high school • Learning quality • Learning approach • SOLO taxonomy • Correlation study

---

L.-H. Zou • M.-L. Zhong • Z.-Y. Wang
School of Chemistry and Environment, South China Normal University, Guangzhou 510006, People's Republic of China

J. Li (✉)
The Education Examination Authority of Guangdong Province, Guangzhou 510631, People's Republic of China
e-mail: xuefeng020@126.com

W.-C. Chen
No. 1 High School of Doumen, Zhuhai 519100, People's Republic of China

B. Zhang et al. (eds.), *International Conference on Science Education 2012 Proceedings: Science Education: Policies and Social Responsibilities*,
DOI 10.1007/978-3-642-54365-4_14,

14.1 Introduction

The learning style has been studied for a long time, and the concept has been accepted and further elaborated into the learning approach. The approaches to learning have been widely studied, specifically on the relations among learners' interests and tendencies, strategies and methods in learning, and cognitive levels (Marton and Saljo 1976; Biggs 1987, 1995; Gao 2000; Marton and Booth 1997). Marton et al., from a constructivist learning perspective, studied the relations between the motives and outcomes of learning and put up the view of "the learning view + learning strategies = learning methods, which always affects the learning effects" (Marton and Booth 1997). Biggs (1991) researched learning motives; discussed the meta-learning, learning concept, and learning strategies based on cognitive psychology; and explained the point of "the learning motive + learning strategies = learning methods, which always affects the learning effects." They also brought forth three styles of learning (surface style, deep style, and achievement style) and quantitatively examined the relations between the learning methods and outcomes (Bernardo 2003; Biggs 1991; Biggs and Watkins 1998; Hattie and Watkins 1981; Sachs and Gao 2000; Trigwell and Prosser 1991; Watkins 1994; Zhang and Bernardo 2000).

Learning outcomes typically refer to the changes and developments of the cognitive and emotional aspects after the students' learning, and the function of the result analysis is to identify those changes and developments. Gagne divided the learning outcomes into five types: intellectual skills, cognitive strategies, verbal information, motor skills, and attitudes, and each type of learning results had necessary learning conditions (Gagne 1977). Biggs and Collis (1982) developed the SOLO taxonomy to qualitatively evaluate the qualities of students' learning outcome. Biggs (1999) represented the SOLO taxonomy graphically as shown in Fig. 14.1.

The SOLO taxonomy is a well-established system for evaluating the levels of learning quality and is becoming widely used in education. It describes five major hierarchical levels of structure, with each lower structure forming the basis of another higher-level structure and the complexity of the five levels sequentially incremental. Compared to other classifications, the SOLO taxonomy with a clear hierarchy is more directly based on the learning theory. There is an internal consistency between the levels of SOLO and the statements of most evaluating levels in PISA (Li et al. 2011).

By application of the SOLO, Chick, Lake, Van Rossum, and others believed in its general, comprehensive, and objective standards for testing the students. The SOLO taxonomy was comprehensively applied in different subjects, such as mathematics, biology, and language (Chick 1998; Lake 1999; Van Rossum and Schenk 1984). Chan et al. (2002) added some sublevels into each SOLO structure level, which made the classifications more accurate. What's more, he compared SOLO with the Broome taxonomy and the Thought Reflecting taxonomy and concluded that the SOLO taxonomy was suitable for evaluating different kinds of learning outcomes, which was consistent with the previous study of Trigwell and Prosser (1999).

In recent years, Gao et al. (Gao and Wu 2004; Wu and Huang 2009; Wu et al. 2008, 2009) applied the SOLO taxonomy to evaluate the quality of learning and obtained

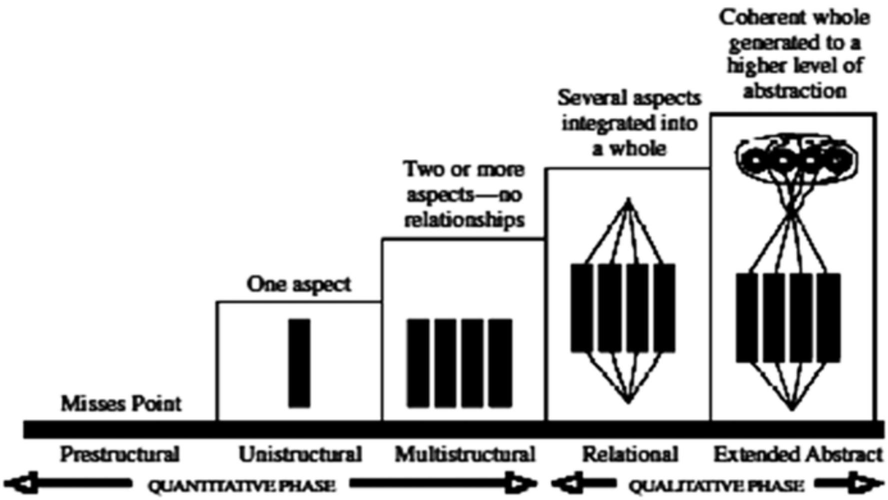


Fig. 14.1 Graphic representation of the structure of the observed learning outcome (SOLD) taxonomy (Biggs 1999)

very good results. Similarly, Li and her colleagues applied SOLO taxonomy to study the chemistry learning level development of high school students (Li 2010, 2011; Zhou 2011). Gao (2000) studied the relationship between learning processes and outcomes. However, we still don't know much about the correlation between learning processes and outcomes for high school students. In this research, we applied the SOLO taxonomy in chemical tests and studied the relationship between students' learning quality and their learning approaches. The results will inform chemistry teachers and students in improving their chemistry teaching and learning.

This study intends to answer the following questions:

(a) What is the correlation between learning outcomes and learning approaches?
(b) What is the distribution pattern of learning outcomes and learning approaches based on the SOLO level characterization?

14.2 SOLO Level Characterization

14.2.1 Methods

Data on students' learning approaches were obtained through a survey using the "Students Learning Process Questionnaire" (LPQ), and a total of 1,402 students were given the questionnaire, 1,213 of which were returned. Data on students' learning quality were obtained through a SOLO test, and a total of 1,402 students completed the test with valid responses.

Table 14.1 Student learning process questionnaire

Learning approach	Dimension	Item	Score	Total score
Surface learning	Motive	1, 7, 13, 19, 25, 31, 37	35	70
	Strategy	4, 10, 16, 22, 28, 34, 40	35	
Deep learning	Motive	2, 8, 14, 20, 26, 32, 38	35	70
	Strategy	5, 11, 17, 23, 29, 35, 41	35	
Achievement learning	Motive	3, 9, 15, 21, 27, 33, 39	35	70
	Strategy	6, 12, 18, 24, 30, 36, 42	35	

Table 14.2 Description of SOLO levels for the chemical test

Symbol	Rating description
P	Prestructure level
U1	Unit-structure level
M2	Multi-structure level with two cognitive dimensions
M3	Multi-structure level with two cognitive dimensions
MA	Transition-structure level from multi-structure to relational structure
R1	Relational structure with one relationship
R1A	Transition-structure level from R1 to R2
R2	Relational structure with two relationships
R3	Relational structure with three or more relationships
RA	Transition-structure level from R1 to E1
E1	Lower extended-abstract structure
E2	Higher extended-abstract structure

Before the above test and survey, school teaching quality in Guangdong province was assessed, and five schools, i.e., S, N, J, D, and Z secondary schools, were chosen for this study. Teaching quality of these schools was overall above average, although different levels of classes in these schools existed. Students of Grade 11 and Grade 12 from the above five high schools completed the LPQ as well as the SOLO content test related to high school chemistry after they studied the topic of "chemical reaction principle" during their chemistry course.

The LPQ contains six scales, including surface learning motive rating scale, deep learning motive rating scale, achievement learning motive rating scale, surface learning strategy rating scale, deep learning strategy rating scale, and achievement learning strategy rating scale. Each of the scales contains six questions. A description of the LPQ is shown in Table 14.1.

The SOLO test on "chemical reaction principle" included six topic items. Within each item, there were various subitems. Each subitem had one highest SOLO structure level. According to the SOLO structure characteristics, we gave each student response a SOLO level, then scored the SOLO levels of subitems, and finally calculated the total score on the test. A description of the SOLO levels for the chemical test is shown in Table 14.2.

Data were analyzed by using SPSS 17.0 software. Descriptive statistics, *t*-test, and correlation test were conducted. For 1,212 test subjects, Cronbach's α-coefficient was 0.807, indicating that the SOLO test results were acceptable in reliability.

Table 14.3 Cronbach's α-coefficients in LPQ and before the results

			Reliability value (Cronbach's α-coefficient)					
			Surface learning		Deep learning		Achievement	
Test place	Test time	*N*	Motive	Strategy	Motive	Strategy	Motive	Strategy
This LPQ	2011–2012	1,402	0.561	0.586	0.722	0.759	0.698	0.758

For 1,402 questionnaire subjects, Cronbach's α-coefficients were presented in Table 14.3. We can see that Cronbach's α-coefficients ranged from 0.561 to 0.759.

14.3 Results and Analysis

14.3.1 Correlation Between Learning Outcomes and Learning Approaches

In order to examine if the students' learning approaches were correlated with their learning outcomes, the Pearson correlation coefficient between the two variables was calculated. The results are shown in Table 14.4.

From Table 14.4, we can see that learning outcomes had very significant correlations with deep and achievement learning approaches, respectively, while appeared to be significantly correlated with the surface learning approach. That is, for surface learning approaches, students' learning outcomes were significantly correlated with their learning strategies. For deep learning approaches, students' learning outcomes were significantly correlated with deep motives and deep strategies. For achievement learning approaches, both achievement motives and achievement strategies were very significantly correlated with learning outcomes.

Multivariate analysis of variance (MANOVA) was conducted to examine simultaneously the effects of various learning approaches on learning outcomes; the results are shown in Table 14.5.

From Table 14.5, we see that the F values for surface strategy, achievement motive, and achievement strategy were 1.901, 1.570, and 2.176, respectively, and the probabilities for those F values were 0.005, 0.033, and 0.001, less than 0.05, rejecting the null hypothesis. Thus, there were statistically significant effects of the surface strategy, achievement motivation, and achievement strategy on student learning outcomes. There were no statistically significant effects for other learning approaches on student learning outcomes.

14.3.2 Distribution of Learning Outcomes and Learning Approaches Based on the SOLO Level Characterization

A total of 11 classes from three grades taught by three different teachers in high school D were chosen for this analysis. We classified students into three different

Table 14.4 Correlation between learning approaches and learning outcomes

Correlation analysis		LO	SM	SS	SLA	DM	DS	DLA	AM	AS	ALA
LO	*r*	1	0.051	0.065*	0.066*	0.105**	0.069*	0.096**	0.106**	0.086**	0.116**
	Sig. (two tailed)	?	0.078	0.024	0.021	0.000	0.016	0.001	0.000	0.003	0.000
	N	1,213	1,213	1,213	1,213	1,213	1,213	1,213	1,213	1,213	1,213

Note: *LO* learning outcome, *SM* surface motive, *SS* surface strategy, *SLA* surface learning approach, *DM* deep motive, *DS* deep strategy, *DLA* deep learning approach, *AM* achievement motive, *AS* achievement strategy, *ALA* achievement learning approach
*Significant at 0.05 level (two tailed)
**Significant at 0.01 level (two tailed)

Table 14.5 The intergroup effect test results of MANOVA

Function: learning outcome					
Source	Type III sum of squares	df	Mean square	*F*	Sig.
Alignment model	90,625.328[a]	309	293.286	1.264	0.005
Interface	121,870.512	1	121,870.512	525.053	0.000
Surface motive	6,559.684	25	262.387	1.130	0.300
Surface strategy	11,033.543	25	441.342	1.901	0.005
Surface learning approach	11,868.970	45	263.755	1.136	0.252
Deep motive	8,495.053	25	339.802	1.464	0.067
Deep strategy	5,280.784	25	211.231	.910	0.592
Deep learning approach	14,595.430	46	317.292	1.367	0.055
Achievement motive	9,839.875	27	364.440	1.570	0.033
Achievement strategy	13,134.391	26	505.169	2.176	0.001
Achievement learning approach	14,568.176	47	309.961	1.335	0.068
Error	209,596.094	903	232.111		
Sum	4,801,359.000	1,213			
Sum after alignment	300,221.423	1,212			

[a]R square = 0.302 (Alignment R square = 0.063)

categories according to their highest scores gained in three learning approaches (e.g., if a student scored the highest in deep approach, then his or her learning approach was classified into deep approach). Then, with class as a unit, the percentages of students in the three learning approaches were computed. Table 14.6 and Fig. 14.2 present the results.

The result of a more detailed analysis of learning outcome features (the percentage of each SOLO level) in high school D on one sample item (item 4) was shown in Table 14.7 and Fig. 14.3 below.

From Table 14.6 and Fig. 14.2, we see that most students in Class 201 used surface approach. From Table 14.7 and Fig. 14.3, we see that Class 201 students at R1, R1A, and R2 levels had percentages of 44.44 %, 14.20 %, and 9.88 %, respectively. And the total was 68.52 %, which is the lowest proportion among three classes. Students at M2, U, and P levels had percentages of 19.14 %, 7.41 %, and 4.94 %, respectively, with a total of 31.49 %, the highest proportion among the three classes.

Further, from Table 14.6 and Fig. 14.2, we see that most students from class 204 used achievement approaches. From Table 14.7 and Fig. 14.3, we see that students of Class 204 at relational R1, R1A, and R2 levels had a total percentage of 72.99 %, while the other students at multi-structure or below levels accounted for 27.01 %.

Similarly, from Table 14.6 and Fig. 14.2, we see that most of students from Class 218 used the deep learning approach. From Table 14.7 and Fig. 14.3, we see that Class 218 students at relational R1, R1A, and R2 levels accounted for 79.28 %, which was the highest, while other students at multi-structure or below level accounted for 27.01 %, the lowest percentage among the three classes.

Table 14.6 Percentages of student number in three classes on three learning approaches in high school D

Class	Sample size	Surface approach (%)	Deep approach (%)	Achievement approach (%)
Class 201	48	45.83	29.17	25.00
Class 204	48	25.00	35.42	39.58
Class 208	30	10.00	73.33	16.67

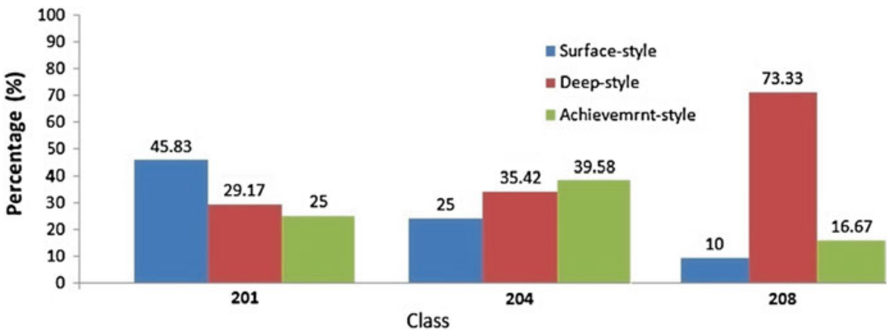


Fig. 14.2 Percentages of student number in three classes on three learning approaches in school D

Table 14.7 Learning outcome feature (the percentage of each SOLO level) in item 4 in school D

Class	P (%)	U (%)	M2 (%)	R1 (%)	R1A (%)	R2 (%)
Class 201	19.14	7.41	4.94	44.44	14.20	9.88
Class 204	11.68	8.03	7.30	51.09	2.19	19.71
Class 218	7.21	6.31	7.21	59.46	0.00	19.82

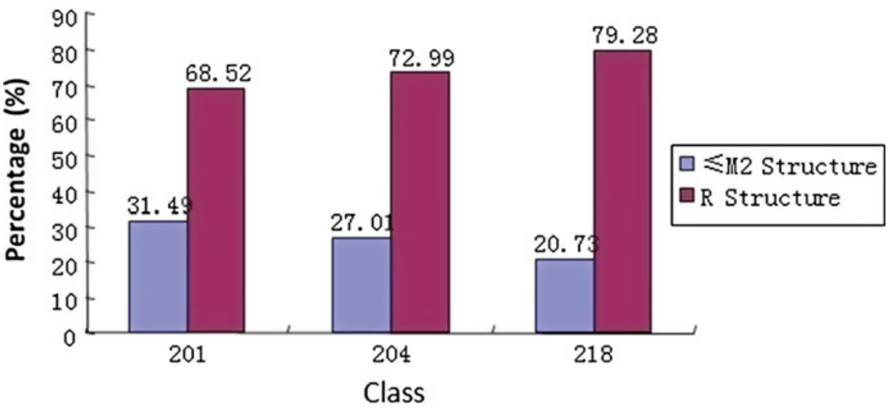


Fig. 14.3 Learning outcome feature (the percentage of each SOLO level) in item 4 in school D

In summary, there was a relationship between learning approaches and learning outcome under the same teaching approach. And a deep learning approach was associated with a better learning outcome.

In general, students got higher SOLO levels on content test when they used deep learning approaches. For example, students in Class 218 using deep learning approaches were on the top in percentage in relational structure levels, whereas their percentages were lowest in different multi-structure levels.

Students using surface learning approaches would score the worst results. For example, the percentages of students in Class 201 who adopted surface learning approaches were lowest in relational structure levels, whereas their percentages were on the top in different multi-structure levels.

When students study by the achievement learning, the results fall in between the results by the deep learning approach and by the surface learning approach.

14.4 Discussions

The results of this study are informative to research the relationship between learning outcome and learning approach using SOLO test and LPQ. First it demonstrated the anticipated relations between learning approaches and the quality of learning outcome. This is consistent with previous findings (Chen 2010; Entwistle and Tait 1990; Marton and Saljo 1984; Prosser and Millar 1989). However, neither of those studies included a measure of the quality of chemistry learning outcomes of high school students. Our study suggests that (1) SOLO sublevels are beneficial to a much accurate classification of students' responses; (2) SOLO tests can provide qualitative and quantitative evaluation of quality of learning outcomes; and (3) there is some evidence of relationship between approaches and quality of learning outcomes.

In future research, we can continue SOLO tests on chemistry to measure the students learning outcomes, but need to create better SOLO items. Besides, we should do some work to develop the LPQ on chemistry. Because deep learning approach is related to better leaning outcomes, so, if the results of this study can be replicated, teachers should pay much attention to help students in using deep learning approach to study. In our previous study (give citation), there were some differences in learning approaches between female and male students; more study is needed on this.

14.5 Conclusions

On the one hand, when using the surface learning approach, students' learning outcomes are related to their learning strategies. On the other hand, a deep learning approach depends significantly on deep motive and deep strategy. Finally, students' learning outcomes are statistically significantly correlated with achieving motive and strategy in terms of achieving approach.

Therefore, it is suggested that in order to achieve better learning outcomes, teachers should take students' individualities into account in the teaching process and try to stimulate students' motive for learning and change their learning approaches to deep and achieving ones.

Acknowledgment The study reported in this article was part of a research project of Guangdong Provincial Education Science Research Twelfth Five-Year Plan (No. 2011TJK112).

References

Bernardo, A. B. I. (2003). Approaches to learning and academic achievement of Filipino students. *The Journal of Genetic Psychology, 164*(1), 101–114.

Biggs, J. B. (1987). *Student approaches to learning and studying* (Research monograph, pp. 10–11). Melbourne: Australian Council for Educational Research.

Biggs, J. B. (1991). Approaches to learning in secondary and tertiary students in Hong Kong: Some comparative studies. *Educational Research Journal, 6*, 27–39.

Biggs, J. B. (1995). Assessing for learning: Some dimensions underlying new approaches to educational assessment. *The Alberta Journal of Educational Research, 41*(1), 1–17.

Biggs, J. B. (1999). What the students does: Teaching for enhanced learning. *High Education Research & Development, 18*(1), 57–75.

Biggs, J. B., & Collis, K. F. (1982). *Evaluating the quality of learning: The SOLO taxonomy* (pp. 198–199). New York: Academic.

Biggs, J. B., & Watkins, D. A. (1998). Classroom learning: Educational psychology for the Asian teacher. *Asia Pacific Journal of Education, 18*(1), 97–103.

Chan, C. C., Hong, J. H., & Chan, M. Y. C. (2002). Applying the structure of the observed learning outcomes (SOLO) taxonomy on student's learning outcomes: An empirical study. *Assessment and Evaluation in Higher Education, 27*(6), 511–527.

Chen, W. C. (2010). *Related research on students' learning methods and results-Take No. 1 high school of Doumen in Zhuhai as an example*. Guangzhou: South China Normal University.

Chick, H. (1998). Cognition in the formal modes: Research mathematics and the SOLO taxonomy. *Mathematics Education Research Journal, 10*(2), 4–26.

Entwistle, N., & Tait, H. (1990). Approaches to learning, evaluations of teaching, and preferences for contrasting academic environments. *Higher Education, 19*, 169–194.

Gagne, R. M. (1977). *The conditions of learning*. New York: Holt, Rinehart and Winston.

Gao, L. B. (2000). Research on learning view, teaching view and description of the phenomenon analytics. *Journal of South China Normal University (Social Science Edition), 3*, 97–104.

Gao, L. B., & Wu, W. N. (2004). How to grade for open-ended test items? An introduction to two qualitative grading methods. *Journal of Subject Education, 8*, 1–5.

Hattie, J., & Watkins, D. (1981). Australian and Filipino investigations of the internal structure of Biggs' new study process questionnaire. *British Journal of Educational Psychology, 51*(2), 241–244.

Lake, D. (1999). Helping students to go SOLO: Teaching critical numeracy in the biological sciences. *Journal of Biological Education, 33*(4), 191–198.

Li, X. (2010). *Study on cognitive development of chemical equilibrium for senior school*. Guangzhou: South China Normal University.

Li, J. (2011). *Exploration of an assessment tool based on SOLO taxonomy and study on chemistry learning level development of high school students*. Guangzhou: South China Normal University.

Li, J., Gao, L. B., & Cao, Q. M. (2011). A comparative study of the levels of SOLO and the levels of appraisal grades of PISA. *Curriculum, Teaching Material and Method, 31*(4), 91–96.

Marton, F., & Booth, S. (1997). *Learning and awareness* (p. 109). Mahwah: Erlbaum.

Marton, F., & Saljo, R. (1976). On qualitative differences in learning: Outcome and process. *British Journal of Educational Psychology, 46*(1), 4–11.

Marton, F., & Saljo, R. (1984). Approaches to learning. In F. Marton, D. Hounsell, & N. J. Entwistle (Eds.), *The experience of learning* (pp. 36–55). Edinburgh: Scottish Academic Press.

Prosser, M., & Millar, R. (1989). The how and what of learning physics. *European Journal of the Psychology of Education, 4*(4), 513–528.

Sachs, J., & Gao, L. B. (2000). Item-level and subscale-level factoring of Biggs' learning process questionnaire (LPQ) in a mainland Chinese sample. *British Journal of Educational Psychology, 70*(3), 405–418.

Trigwell, K., & Prosser, M. (1991). Relating approaches to study and quality of learning outcomes at the course level. *British Journal of Educational Psychology, 61*(3), 265–275.

Trigwell, K., & Prosser, M. (1999). *Understanding learning and leaching: The experience in higher education* (p. 4). Buckingham: SRHE and Open University Press.

Van Rossum, E. J., & Schenk, S. M. (1984). The relationship between learning conception, study strategy and learning outcome. *British Journal of Educational Psychology, 54*, 73–83.

Watkins, D. (1994). Is the Asian learner a rote learner? A Malaysian perspective. *Contemporary Educational Psychology, 19*(4), 483–488.

Wu, W. N., & Huang, C. B. (2009). Senior high school physics SOLO items and SOLO grading methods. *Journal of Foundation Education Course*, (12): 52–54.

Wu, W. N., Gao, L. B., & Li, J. (2008). Research on learning process and teaching approach assessment. *Education Measurement and Evaluation (Theory version)*, (12): 4–7.

Wu, W. N., Li, J., & Kong, H. S. (2009). SOLO item design and quality detection. *Education Measurement and Evaluation (Theory version)*, (3): 45–48.

Zhang, L. F., & Bernardo, A. B. I. (2000). Validity of the learning process questionnaire with students of lower academic attainment. *Psychological Reports, 87*, 284–290.

Zhou, M. Y. (2011). *Study on cognitive development of electrochemistry for senior school students by SOLO taxonomy*. Guangzhou: South China Normal University.

Zou, L. H. (2012). *The study on the relativity of senior school student's learning outcome on chemistry between learning styles and teaching methods*. Guangzhou: South China Normal University.

Chapter 15
Laboratory-Based Scaffolding Strategies for Learning School Science

Au Sau Kheng and Tan Kok Siang

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, J Learn Disabil 31: 344–364, 1998; Davis 2003; Pea, J Learn Sci 13(3): 423–451, 2004). Under Vygotsky's influence, an in-depth empirical study was done on scaffolding processes by Wood, Brunner, and Ross. Wood and co-workers (J Child Psychol Psychiatry 17(2): 89–100, 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 redefined and reinterpreted 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.

A.S. Kheng (✉) • T.K. Siang
National Institute of Education, Singapore, Singapore
e-mail: au_sau_kheng@moe.gov.sg; koksiang.tan@nie.edu.sg

B. Zhang et al. (eds.), *International Conference on Science Education 2012 Proceedings: Science Education: Policies and Social Responsibilities*,
DOI 10.1007/978-3-642-54365-4_15,

Keywords Scaffolding • Metaphor • Support • Tools • Fade

15.1 Introduction

Over the past 35 years, the concept of scaffolding has been widely used as a metaphor to support teaching and learning. This metaphor was used to describe the support provided by parents, teachers, and mentors to assist learners in mastering new concepts, skills, or levels of understanding. This term describes the nature of an essential support that provides temporary assistance that enables the learner to advance to the next level in knowledge and understanding (Maybin et al. 1992). The original concept of scaffolding was developed for studies in cognitive and linguistic development of young learners with one-to-one tutelage. When translating scaffolding to current classroom practices, especially in other subjects or areas of learning, teachers may face difficulty in aligning practices to the associated theories. This paper documents an initial effort to apply scaffolding in the learning of science in the school laboratory, especially in helping students learn practical skills.

While scaffolding remains an abstract concept with its limitations, educators still find the concept appealing as it is a term that resonates with teachers' conception of successful classroom interventions (Mercer 1994). Hogan and Pressley (1997) termed it as a support provided within a learner's zone of proximal development (ZPD), the developmental area that Vygotsky (1978) defined as between what a learner could do alone and what she or he could do with the assistance of a more capable other. In recent years, scaffolding has also been referred to as facilitation strategies to help teachers to cope with the changes within the classroom (Quintana et al. 2004).

15.2 What Is Scaffolding?

The idea of scaffolding to support learning was introduced more than three decades ago by Wood et al. (1976). Since then, studies had been done on the teaching approaches and scaffolding strategies in reading, writing instruction, learning and teaching mathematics and science, historical inquiry, technology-enhanced learning environments, and even in student learning (Hammond and Gibbons 2006; Hobsbaum et al. 1996; Anghileris 2006; Holbrook and Kolodner 2000; Woelders 2007; Chen and Bradshaw 2007; Simons and Klein 2007). The bulk of research on scaffolding has been drawn from many of such studies.

The original notion of scaffolding applied to interactions between an expert and a learner, the former is usually a teacher or a parent who provides the help needed to move the learner forward (Wood et al. 1976). In essence, it was a one-on-one interaction where the expert, being the knowledgeable and skillful one, provided just enough support the learner needed to complete an activity or task successfully.

The interaction between them allowed the expert to monitor the learner's progress and provide the appropriate support. The support was then gradually removed once the learner was in control of her or his learning. In an education context, instructional scaffolding is known to enable a child or a novice to solve a problem, carry out a task, or achieve a goal that she or he cannot accomplish on her or his own (Wood et al. 1976). The support can progressively "fade" away when there is no longer a need for it. This fading of the support, one of the key theoretical features of scaffolding, enables the learner to be responsible for her or his learning.

Many studies and theories supporting scaffolding as a teaching strategy or approach came from Lev Vygotsky. He introduced the notion of zone of proximal development, or ZPD, in his social constructivist theory and emphasized that children's learning must be guided and supported by teacher modeling and assistance in this zone (Byrnes 2001). ZPD is the hypothetical, dynamic region in which learning and development take place. Vygotsky (1978) defined it as "the distance between the actual developmental level as determined by independent problem solving and the level of potential development as determined through problem solving under adult guidance or in collaboration with more capable peers." The theoretical basis of scaffolding mirrors that of a ZPD that assumes learning occurs when the child is ready to grow cognitively. Vygotsky explained that teachers could act as "scaffolds" as they guide children toward making progress independently and children could be taught within their ZPD for intellectual growth. Teachers could then model the skill to be internalized and attempt to remove the scaffolds gradually as the child gains mastery of the skill (Byrnes 2001). As a construct that is closely linked to ZPD, instructional scaffolding is a mechanism for observing the process by which the learner's potential learning is effected (Stone 1993). From this perspective, the nature of instructional scaffolding can be viewed as a provision of essential supports to promote learning of concepts and skills.

Many studies in science classrooms have used scaffold environments for teaching and learning, but the notion of scaffolding in these studies has evolved from the original idea of interactions between two individuals to the use of software, technologies, artifacts, questions, reflections, and hints as supports for learning (Chen and Bradshaw 2007; Sherin et al. 2004; Davis and Linn 2000). Stone (1998) argues that the metaphor, "scaffolding," has not been aligned to a social constructivist theoretical tradition. It has also not been utilized consistently with its heritage, and therefore care needs to be taken when using it in different contexts and environments. As a result of the liberal use of the metaphor, Meyer (1993) argues that using scaffolding as an atheoretical metaphor offers a rich and compelling way for providing support instruction and learning in the classroom and that researchers should not separate the implications of scaffolded instruction for practice and research from their theoretical foundation, such as the social interactive context. It was actually Palincsar (1998) who pointed out that it is the "atheoretical use of scaffolding that has become problematic." She urged researchers to reposition the metaphor in its theoretical framework and consider ways in which contexts and activities (and not just individuals) scaffold learning. Others, like Stone (1998) and Puntambekar and Hubscher (2005), have also contested the use of this metaphor.

Wood et al. (1976) first mentioned scaffolding when they stated that the interaction between a tutor and another individual generally involves a "'scaffolding' process that enables a child or novice to solve a problem, carry out a task or achieve a goal which would be beyond his unassisted efforts." In some articles after Wood et al.'s (1976) original work, the exact words were cited explicitly as a definition of scaffolding. Some other definitions that place emphasis on educational technology kept very closely to Wood et al.'s original definition. For example, scaffolding is referred to as support provided so that the learner can engage in activities that would otherwise be beyond their abilities (Jackson et al. 1998; cited in Puntambekar and Hubscher 2005). Scaffolds are tools, strategies, and guides which support students in attaining a higher level of understanding, one which would be impossible if students were to work on their own (Brush and Saye 2001; cited in Sherin et al. 2004). Scaffolding enables the learner to achieve goals or accomplish processes normally beyond their reach (Krajcik et al. 1998).

The next idea, "distributed scaffolding," is coined by Puntembekar and Kolodner (1998; in press). This phrase refers to instructional designs that sequence and integrate a variety of social and material supports (cited in Tabak 2004). In this context, scaffolding refers to the titrated support that helps learners learn through activity. It helps learners perform tasks that are outside their independent reach and consequently develop the skills necessary for completing such tasks independently (Rogoff 1990; Wertsch 1979; Wood et al. 1976; cited in Tabak 2004). In short, it is a collection of material and social supports that enable learners to learn discipline such as science by "doing science."

Tabak (2004) described distributed scaffolding (Puntambekar and Kolodner 1998) as an emerging approach in the design of supports for rich learning environments that are intended to help students develop disciplinary ways of knowing, doing, and communicating. In this scaffolded environment, multiple forms of support are provided through different means to address the complex and diverse learning needs of the learners. It is the metaphor that made the multiple supports explicit, in contrast to the original conception of scaffolding in relation to parent-child interactions, where there is just a single means of support. Her framework formalized distributed scaffolding and delineated the different forms or patterns that the scaffolding can take and the functions that these different patterns perform. Differentiated scaffolds, redundant scaffolds, and synergistic scaffolds are three complementary patterns associated to distributed scaffolding.

Redundant scaffolds have been explicitly identified as a design strategy for distributed scaffolding. It involves different means of support that target the same need but are enacted at different points in time in the curriculum to provide titrated levels of support (Puntambekar and Kolodner 2005). Figure 15.1 depicts the redundant scaffolds model. As a result of the difference in student competencies, there is a need for different types and levels of support to meet the particular learning needs.

When scaffolding is provided in multiple formats, there are more chances for students to notice and take advantages of the environment's affordances (cited in Puntambekar and Kolodner 2005). Providing good and effective scaffolding may mean that a learner is provided with support that can enable him or her to function

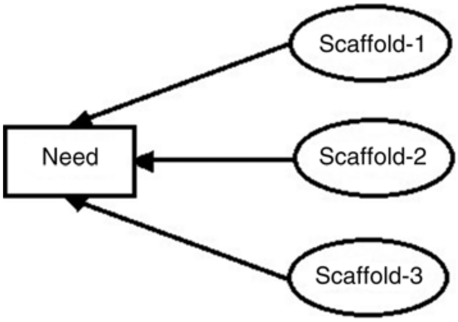


Fig. 15.1 Redundant scaffolds model (Tabak 2004)

independently. The best scaffoldings are the ones that can be faded because the learner will eventually (through the scaffolds) internalize the processes he or she is being helped to accomplish (Rogoff 1990; cited in Puntambekar and Hubscher 2005). Tabak argues that the tasks in these contexts are more complex and extend over longer periods of time than the tasks depicted in the classical examples of scaffolding. As such, scaffolding needs to change accordingly over time in response to the changing needs of students and the curriculum.

Chen and Bradshaw (2007) said that merely presenting information generally will not cause students to develop accurate and integrative knowledge that fosters the understanding of pragmatic principle(s) and dynamic stances toward new knowledge. There should be intentional instructional supports to elicit such knowledge building processes. They felt that students need to be prompted to think about new materials in such a way that they transform the materials, thus constructing knowledge. Studies have also shown that question prompts, a type of instructional supports, can effectively promote students' knowledge integration (Davis and Linn 2000). Different question prompts may serve different needs and purposes for students. Davis and Linn (2000) also studied the effects of guided questions on metacognition skills, knowledge integration, and problem solving. Their study also reported how reflective prompts were used to support knowledge integration and encourage reflection at a level that students did not generally consider.

15.3 How Scaffolding Is Used

In terms of learning, teachers are responsible for providing the scaffolding for classroom instruction. Scaffolding used in the classroom is only a temporary support which has to be removed when learners are able to independently demonstrate their competence and articulate knowledge without the support. To distinguish scaffolding from just mere help given by a teacher to accomplish a task, there should be some evidences that the teacher has the intention for the learner to develop a specific skill, learn a specific concept, or achieve a particular level of understanding. There should also be evidences indicating how the teacher could monitor a learner's success in a

Table 15.1 Frequency of research in the 43 selected articles

Research foci as reported by Lin et al. (2012)	1995–1999	2000–2004	2005–2009	Total
Teacher education	0	2 (4.65 %)	3 (6.98 %)	5 (11.63 %)
Learning conceptions	0	2 (4.65 %)	1 (2.33 %)	3 (6.98 %)
Learning contexts	1 (2.33 %)	10 (23.26 %)	20 (46.51 %)	31 (72.09 %)
History, philosophy, epistemology, and NOS	0	0	1 (2.33 %)	1 (2.33 %)
Curriculum	0	0	2 (4.65 %)	2 (4.65 %)
Assessment	0	0	1 (2.33 %)	1 (2.33 %)
Total	1 (2.33 %)	14 (32.56 %)	28 (65.12 %)	43 (100 %)

Source: Lin et al. (2012: 443)

task or on how the teacher intends to measure the learner's increased competence or improved level of understanding of a specific learning activity (Maybin et al. 1992).

Many of these evidences are reported by researchers and educators in their studies using various forms of scaffolding or scaffolding experiences or environments. As a result of the frequent use of the metaphor in the teaching and learning environment, it has been redefined and reinterpreted in various ways, based on the learners' needs in these studies. However, 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. Also, its popularity in classroom instruction suggests that teachers believe it contributes to effective classroom instruction and the beneficial effects on school curriculum. Few teachers and educators would have any dispute over the importance of scaffolding in their own learning environments. Despite the many changes and adaptations, most forms of scaffolding, if not all, still aligns with Wood's idea of providing an approved atmosphere to "show" and help the learner complete the task and reach the goal per se (Wood et al. 1976). Thus, it would be useful to unpack the scaffolding tools, strategies, or approaches that have been used in the different scaffolded environments or situations for the purpose of investigating whether the metaphor has transformed over the recent years, particularly in the science education contexts.

In recent years, researchers and educators had been using the scaffolding metaphor in science learning and teaching environments. Lin et al. (2012) identified 43 articles published in the Social Science Citation Index journals between 1995 and 2009. These articles (from various reputable science education journals) provide science educators with empirical evidences regarding the effects of scaffolding on science learning. Lin et al. (2012) did a detailed content analysis of the 43 articles with the purpose of focusing specifically on the clarification on the definition, design, and implementation of scaffolding in science classrooms and research studies for the periods 1995–2009. Table 15.1 is a summary of the various research foci of researchers using the scaffolding metaphor within the science education context across the three 5-year periods that spanned from 1995 to 2009.

This paper aims to present (1) the various forms of scaffolding and the different scaffolding tools, strategies, or approaches in science education and (2) some recent studies in Singapore on the use of scaffolds in science education. We will also report on some of the outcomes from these recent studies in which scaffolding was used to support learners in the learning of experimental skills in the chemistry laboratory.

15.4 Recent Studies on Scaffolding in Singapore Schools

Unlike scaffolding in the general context where there have been many studies, there is apparently a gap in studies involving the use of scaffolding in helping students learn science in the school laboratory. Two recent studies in Singapore schools on the effectiveness of using scaffolding in school science laboratory (Au 2009; Au and Tan 2010) had shown that this is a potential area for more extensive and intensive research to be done. The two studies investigated the effectiveness of scaffolds in laboratory as a means for teachers to help students learn and master curriculum-assessed chemistry practical skills. The focus of both studies was on the types of scaffolds provided during chemistry laboratory practical lessons. Both adopted the concept of distributed scaffolding, an emerging practice among researchers interested in supporting science learning (Raes et al. 2012; Puntambekar and Kolodner 2005) and others such as in history (Li and Lim 2008). This concept involves developing ways of knowing, doing, and communicating and entails a large assortment of learning or support needs (Tabak 2004). The different types of scaffolds used in her study are teacher support, procedural facilitation (a pedagogical technique used in the study of Scardamalia and Bereiter 1985, cited in Pea 2004), prompts and questions, and reflection prompts (Davis 2003). Some of these scaffolds are used as redundant scaffolds. Redundant scaffold is one of the three patterns of distributed scaffolding. As a result of the difference in student competencies, there is a need for different types of support in the chemistry laboratory to meet the particular learning needs. During laboratory work, redundant scaffolds were used because some students may miss opportunities to benefit from a particular scaffold and that some students will require more support than others (Tabak 2004). Redundant scaffolds can provide multiple scaffolds for the same need. This was achieved by providing different types of scaffolds to support the same learning need at different points in the curriculum materials used in the study. The multiple supports used allowed students to have more assistance to complete a task. These also helped students use another scaffold should the first one be missed or had not provided any help. Initial findings of an earlier study on two classes of grade 9 chemistry students (Au 2009) indicated that students who had been through scaffolded lessons performed better than those who did not. These findings suggest that scaffolds may enhance student performance in chemistry laboratory and the students can function independently when the support is removed (faded).

The limitation for this study was that the two classes (XA and XB) perform different sets of experiments. Hence a different survey was conducted with each class of students performing a series of scaffolded tasks, six of which were common to the two classes and the rest different (Au and Tan 2010). Figure 15.2a and b show the responses for each of the scaffolds for the two classes, XA and XB, respectively.

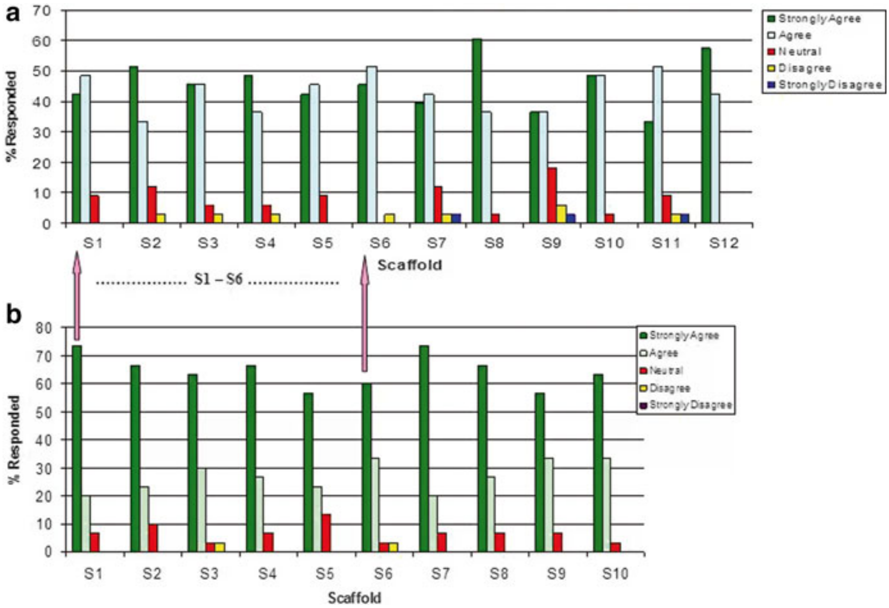


Fig. 15.2 (**a**) Percentage response from X_A. (**b**) Percentage response from X_B

Table 15.2 Percentage of responses to scaffolds S1–S6

Class	% responded (SA and A)	SA (%)	A (%)
X_A	85–97	42–49	33–51
X_B	87–93	60–73	20–33

The findings from the second study (Au and Tan 2010), based on the six common scaffolds of the surveys conducted for classes, XA and XB, indicate that a large number of students in both classes viewed scaffolds that were provided in the scaffold environments of chemistry laboratory helpful in supporting the learning of practical skills and useful for reflection on skills performed. This is observed in the comparable number of "Strongly Agree, SA" and "Agree, A" responses from both classes. Table 15.2 shows the percentage range of responses for both classes.

The percentage response to SA in Table 15.2 indicates that class XB students have a higher percentage response than class XA. This finding may indicate that a greater number of class XB students find scaffolding helpful in chemistry laboratory. A larger number of SA responses from class XB may be attributed to students' experiences in both no-scaffold and scaffold environments for chemistry laboratory. Class XB students were not provided with scaffolds in the first round of the study, but after the second round with scaffolds, more students of the class could make a distinct comparison between scaffold and no-scaffold laboratory environments.

An extension of the research on distributed scaffolding follows after the two earlier studies. It is a project being conducted with 4 classes of secondary 3–4

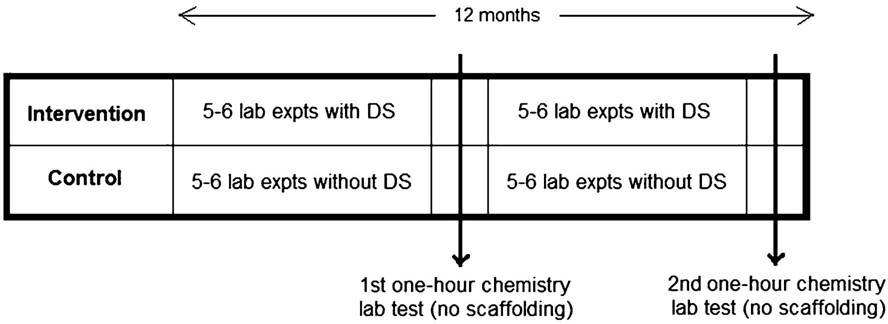


Fig. 15.3 Extended study on the use of distributed scaffolding on two classes (using 11 chemistry lab experiments with and without distributed scaffolding materials)

Table 15.3 Summary of preliminary *t*-test results for the scores of no-scaffold class and scaffold class

Class	No. of students	Mean	SD	*t*	*p*	E S
No-scaffold	34	13.18	2.33	–3.94	0.000	0.93
Scaffold	39	15.03	1.55			

(grades 9–10) students (137) over a 2-year chemistry curriculum. This project probes the effectiveness of distributed scaffolding in the curricular materials for the grades 9–10 chemistry laboratory. In this extended study, multiple supports are provided to scaffold the learning of practical skills with the end goal being the completion of the chemistry experiments safely using the appropriate laboratory techniques. The multiple supports provided include question and reflective prompts (Davis and Linn 2000) and others which are procedural and direct in nature.

Preliminary findings are reported for two classes in the project, the no-scaffold class and the scaffold class. Each class carried out 11 chemistry experiments over a 12-month period. Each experiment was a 1-h experiment which follows the chemistry curriculum schedule. Only for intervention class had been given chemistry laboratory materials supported by distributed scaffolding instructions or notes. A 1-h chemistry laboratory test was administered (without scaffolding) for both classes after 5–6 experiments had been carried out. Another 1-h experiment was administered to each class after the last 5–6 experiments were done. The tests administered (applies for the scaffold class) without scaffolds align with the fading feature of scaffolding. Figure 15.3 summarizes the time line for the chemistry laboratory experiments and the two chemistry laboratory tests the two classes went through over the 12-month period.

The total of the two test scores was used in the *t*-test conducted to compare scores of the two classes. The *t*-test results and the related descriptive statistics are summarized in Table 15.3.

The mean score of the scaffold class ($M = 15.03$, $SD = 1.55$) is significantly higher ($t = -3.94$, $df = 56$, two-tailed $p = 0.000$) than that of the no-scaffold class ($M = 13.18$, $SD = 2.33$). The effect size, estimated with Cohen's d, was 0.93. The preliminary findings show that a scaffolding environment can enhance the learning of practical skills in chemistry laboratory and that scaffolding has a large effect (E S = 0.93) on the performance of practical work in the laboratory.

15.5 Implications and Conclusions

The overall findings of the studies on scaffolds provided in practical work may have implications on student learning of chemistry laboratory skills in school. Findings from our studies also indicate a high potential in using scaffolding as a positive contributing factor to improve student learning, especially in laboratory chemistry tasks. For example, the different types of support also help students in chemistry laboratory lessons. These were especially helpful if the class size is too big for the teacher to give effective one-to-one attention. Scaffolds like those used in this study's worksheets or presented visually next to instruments in the laboratory may be effective supports to assist students in the learning and mastery of practical skills. Also, by providing different multiple scaffolds in chemistry, laboratory students' learning of practical skills can be better enhanced because students have indicated that the scaffolds were helpful in their learning process. Finally, our studies also provided new insights on how scaffolded learning environments can help improve student learning of laboratory skills. Thus, findings from these initial studies can pave the way for more in-depth studies on how scaffolding help students learn and master laboratory skills in a more meaningful and sustainable way.

References

Anghileri, J. (2006). Scaffolding practices that enhance mathematics learning. *Journal of Mathematics Teacher Education, 9*, 33–52.

Au, S. K. (2009, October). *Scaffolding chemistry laboratory*. Paper presented at International Conference of East-Asian Science Education 2009, Taipei.

Au, S. K., & Tan, K. S. (2010, January). *Scaffolding chemistry laboratory: Student views of the scaffolds provided in practical work*. Proceedings of the sixth international conference on Science, Mathematics and Technology 2010, Hualien.

Byrnes, B. (2001). *Cognitive development and learning in instructional context* (2nd ed.). Allyn/Bacon: Needham Heights, M. A.

Chen, C.-H., & Bradshaw, A. C. (2007). The effect of web-based question prompts on scaffolding knowledge integration and ill-structured problem solving. *Journal of Research on Technology in Education, 39*(4), 359–375.

Davis, E. A. (2003). Prompting middle school science students for productive reflection: Generic and directed prompts. *The Journal of the Learning Sciences, 12*(1), 91–142.

Davis, E. A., & Linn, M. C. (2000). Scaffolding students' knowledge integration: Prompts for reflection in KIE. *International Journal of Science Education, 22*(8), 819–837.

Hammond, J., & Gibbons, P. (2006). *What is scaffolding? Teachers' voices 8: Explicitly supporting reading and writing in the classroom* (pp. 8–16). Sydney: National Centre for English Language Teaching and Research, Macquarie University.

Hobsbaum, A., Peters, S., & Sylva, K. (1996). Scaffolding in reading recovery. *Oxford Review of Education, 22*(1), 17–35.

Hogan, K., & Pressley, M. (Eds.). (1997). *Scaffolding student learning: Instructional approaches and issues* (Advances in learning & teaching, pp. 74–107). Cambridge, MA: Brookline Books.

Holbrook, J., & Kolodner, J. L. (2000). Scaffolding the development of an inquiry-based (science) classroom. In B. Fishman, & S. O'Connor-Divelbiss (Eds.), *Fourth international conference of the learning sciences* (pp. 221–227). Mahwah: Erlbaum.

Krajcik, J., Blumenfeld, P. C., Marx, R. W., Bass, K. M., Fredericks, J., & Soloway, E. (1998). Inquiry in project-based science classrooms: Initial attempts by middle school students. *The Journal of the Learning Sciences, 7*, 313–350.

Lajoie, S. P. (2005). Extending the scaffolding metaphor. *Instructional Science, 33*, 541–557.

Li, D. D., & Lim, C. P. (2008). Scaffolding online historical inquiry tasks: A case study of two secondary school classrooms. *Computers & Education, 50*, 1394–1410.

Lin, T. –C., Hsu, Y. –S., Lin, S. –S., Changlai, M. –L., Yang, K. –Y., & Lai, T. –L. (2012). A review of empirical evidence on scaffolding for science education. *International Journal of Science and Mathematics Education, 10*, 437–455.

Maybin, J., Mercer, N., & Stierer, B. (1992). 'Scaffolding' learning in the classroom. In K. Norman (Ed.), *Thinking voices: The work of the national curriculum project*. London: Hodder and Stoughton for the National Curriculum Council.

Mercer, N. (1994). Neo-Vygotskian theory and classroom education. In B. Steirer & J. Maybin (Eds.), *Language, literacy and learning in educational practice*. Clevedon/Avon: Multilingual Matters.

Meyer, D. K. (1993). What is scaffolded instruction? Definitions, distinguishing features, and misnomers. In D. J. Leu & C. K. Kinzer (Eds.), *Examining central issues in literacy research, theory, and practice* (pp. 41–53). Chicago: National Reading Conference.

Palincsar, A. S. (1998). Keeping the metaphor of scaffolding fresh—A response to C. Addison Stone's "The metaphor of scaffolding: Its utility for the field of learning disabilities". *Journal of Learning Disabilities, 31*, 370–373.

Pea, R. D. (2004). Commentary: The social and technological dimensions of scaffolding and related theoretical concepts for learning, education, and human activity. *Journal of the Learning Sciences, 13*(3), 423–451.

Puntambekar, S., & Hubscher, R. (2005). Tools for scaffolding students in a complex learning environment: What have we gained and what have we missed? *Educational Psychologist, 40*(1), 1–12.

Puntambekar, S., & Kolodner, J. L. (1998). Distributed scaffolding: Helping students learn in a learning by design environment. In A. S. Bruckman, M. Guzdial, J. L. Kolodner, & A. Ram (Eds.), *Proceedings of the third international conference of the learning sciences (ICLS '98)* (pp. 35–41). Atlanta: Association for the Advancement of Computing in Education.

Puntambekar, S., & Kolodner, J. L. (2005). Toward implementing distributed scaffolding: Helping students learn science from design. *Journal of Research in Science Teaching, 42*(2), 185–217.

Quintana, C., Reiser, B. J., Davis, E. A., Krajcik, J. S., Fretz, E., Duncan, R., et al. (2004). A scaffolding design framework for software to support science inquiry. *The Journal of the Learning Sciences, 13*(3), 337–386.

Raes, A., Schellens, T., Wever, B. D., & Vanderhoven, E. (2012). Scaffolding information problem solving in web-based collaborative inquiry. *Computers & Education, 59*(1), 1–13. doi:10.1016/j.compedu.2011.11.010.

Scardamalia, M., & Bereiter, C. (1985). Research on written composition. In M. C. Wittrock (Ed.), *Handbook of research on teaching* (3rd ed., pp. 778–803). New York: Mac Millan.

Sherin, B., Reiser, B. J., & Edelson, D. (2004). Scaffolding analysis: Extending the scaffolding metaphor to learning artifacts. *Journal of the Learning Sciences, 13*(3), 38–421.

Simons, K. D., & Klein, J. D. (2007). The impact of scaffolding and student achievement levels in a problem-based learning environment. *Instructional Science, 35*(1), 42–72.

Stone, C. A. (1993). What's missing in the metaphor of scaffolding? In E. A. Forman, N. Minick, & C. A. Stone (Eds.), *Contexts for learning: Sociocultural dynamics in children's development* (pp. 169–183). New York: Oxford University Press.

Stone, C. A. (1998). The metaphor of scaffolding: Its utility for the field of learning disabilities. *Journal of Learning Disabilities, 31*, 344–364.

Tabak, I. (2004). Synergy: A compliment to emerging patterns of distributed scaffolding. *Journal of the Learning Sciences, 13*(3), 305–335.

Vygotsky, L. S. (1978). Interaction between learning and development (M. Lopez-Morillas, Trans.). In M. Cole, V. John-Steiner, S. Scribner, & E. Souberman (Eds.), *Mind in society: The development of higher psychological processes* (pp. 79–91). Cambridge, MA: Harvard University Press.

Woelders, A. (2007). *"It makes you think more when you watch things": Scaffolding for historical inquiry using film in the middle school classroom* (The social studies). Washington, DC: Heldref Publications.

Wood, D., Bruner, J. S., & Ross, G. (1976). The role of tutoring in problem solving. *Journal of Child Psychology & Psychiatry & Allied Disciplines, 17*(2), 89–100.

Chapter 16
Argumentation in University Chemistry Education: A Case Study of Practical Investigations from Activity Theory Perspective

Xiaomei Yan

Abstract Argumentation has attracted attentions in science education for over two decades. In particular, argumentation has been recognized for its key role in linking theory and evidence. Meanwhile, tertiary chemistry students have widely acknowledged their challenges in coordinating theoretical knowledge presented in lectures and empirical data gathered through experimentation in laboratory contexts. Therefore, I proposed to explore argumentation, in a specific context, on a chemistry practical course in the university. Moreover, taken the complex learning environment into consideration, this study has employed activity theory as a theoretical framework to reveal the role of argumentation in the second year chemistry practical course in one university in the UK. The data were collected from different sources (including the students, the demonstrators, and the academic tutors) by various methods (such as individual interviews, observations, and the students' experiment reports). Argumentation has been regarded as a necessary scientific skill to acquire instead of being a tool for learning. This has been advocated by the researchers and educators. Moreover, the different features of students' oral arguments in the laboratory and written arguments in their experiment reports have been an implicit and explicit instructional context for these two tasks.

Keywords Argumentation • Activity theory • Tertiary chemistry education • Practical education

X. Yan (✉)
Graduate School of Education, University of Bristol, Bristol, UK
e-mail: x.yan@bristol.ac.uk

B. Zhang et al. (eds.), *International Conference on Science Education 2012 Proceedings: Science Education: Policies and Social Responsibilities*,
DOI 10.1007/978-3-642-54365-4_16,

16.1 Introduction

Over the past few decades, there has been growing attention on research in teaching and learning of argumentation in science education (Lee et al. 2009). The importance of implementing argumentation in science lessons has been acknowledged due to the essential role of argumentation in both scientific inquiry and learning of science (i.e., Boulter and Gilbert 1995; Duschl and Osborne 2002; Zohar and Nemet 2002). However, most of these studies have focused on secondary school students or the preservice science teachers (i.e., Duschl and Osborne 2002; Erduran et al. 2004; Sadler and Donnelley 2006). There is very little research at higher education level with science students. This gap in the research literature leads me to investigate the issue of teaching and learning of argumentation in tertiary science education. Based on review of relevant literatures, explored from the cultural-historical activity theory (CHAT) perspective, the empirical study is specifically guided by the following research questions:

RQ 1. How does argumentation function as a mediating tool in the chemistry practical learning environment?
RQ 2. How do structures, as defined by CHAT, of the chemistry practical course influence the teaching and learning of argumentation?
RQ 3. How does the culture of teaching and learning in the chemistry practical course involve argumentation particularly from a sociohistorical perspective?

16.2 Literature Review

The brief literature review in this section highlights the definitions of argumentation in this study. This section also explores the roles of argumentation in tertiary chemistry practical education.

16.2.1 Definition of Argumentation

Although the importance of constructing evidence-based arguments has been emphasized by researchers (e.g., Driver et al. 2000; Erduran et al. 2004), the definition of argumentation has not been used consistently in the literature of science education (Lawson 2010). This study will focus particularly on the epistemic and discursive aspect of argumentation (Osborne et al. 2004: 995).

As an epistemic task, the activities of argumentation involve the students to reflect on the epistemological ideas about science, such as “what makes a claim scientific, and how such criteria are related to methods that scientists use to generate and to warrant claims” (Sandoval and Millwood 2008: 71). As a discursive practice, according to Driver et al. (2000: 289), argumentation is a process of reasoning “from premises to conclusions… include evaluating evidence, assessing alternatives, establishing the validity of scientific claims, and addressing counter evidence." Therefore, in this study, not only the students' arguments and their process of arguing but also their criteria for arguments and their reasons for arguing in science classes will be explored.

16.2.2 The Role of Argumentation in Tertiary Chemistry Education

Argumentation is one of the critical parts in tertiary chemistry practical education according to QAA[1](2007). Moreover, in the case of chemistry practical education, introducing argumentation might be helpful to bring the meaning to students' learning (i.e., Simon et al. 2006; Kuhn and Udell 2003). Furthermore, examining the practical education from argumentation perspective reveals the contradictions embedded in the culture of teaching and learning. For instance, it leads to question the separation of theory learning in theater lectures and practical skills in the laboratory.

However, there are issues identified by the researchers on implementation of argumentation into science classrooms (i.e., Driver et al. 2000; Erduran et al. 2004; Evagorou and Avraamidou 2008; Jiménez-Aleixandre et al. 2000). These include challenges to teachers' teaching, constraints of assessment, and limits from the class settings. Moreover, Jiménez–Aleixandre (2008: 95) emphasized that these issues "are not independent, but forming part of a systemic whole." However, there is not much literature looking at the argumentation from such a holistic perspective. Accordingly, this study aims to investigate whether the implementation of argumentation in higher education is facing similar challenges. Particularly, cultural-historical activity theory (CHAT) has been employed as a theoretical framework to investigate the complexities surrounding argumentation in this study.

16.3 Theoretical Framework: Activity Theory

Activity theory (CHAT), whose integrity and flexibilities distinguish it from other sociocultural frameworks (Nardi 1996), has been proposed as a useful framework for educational research (Roth and Lee 2007: 205). CHAT focuses on the social activities mediated by tools within the certain historical context (Langemeyer and Nissen 2005). Although CHAT is an evolving theory, the basic principles of CHAT, which includes the historical context situatedness, the multivoicedness, the collective knowledge building in the community, the tool mediation, and the object orientation of the activity system (Daniels 2001), might be agreed on with the researchers using CHAT. In this study, CHAT provides a heuristic lens in asking useful questions to

[1] Retrieved from http://www.qaa.ac.uk/Publications/InformationAndGuidance/Documents/chemistryfinal.pdf on 11/12/2012.

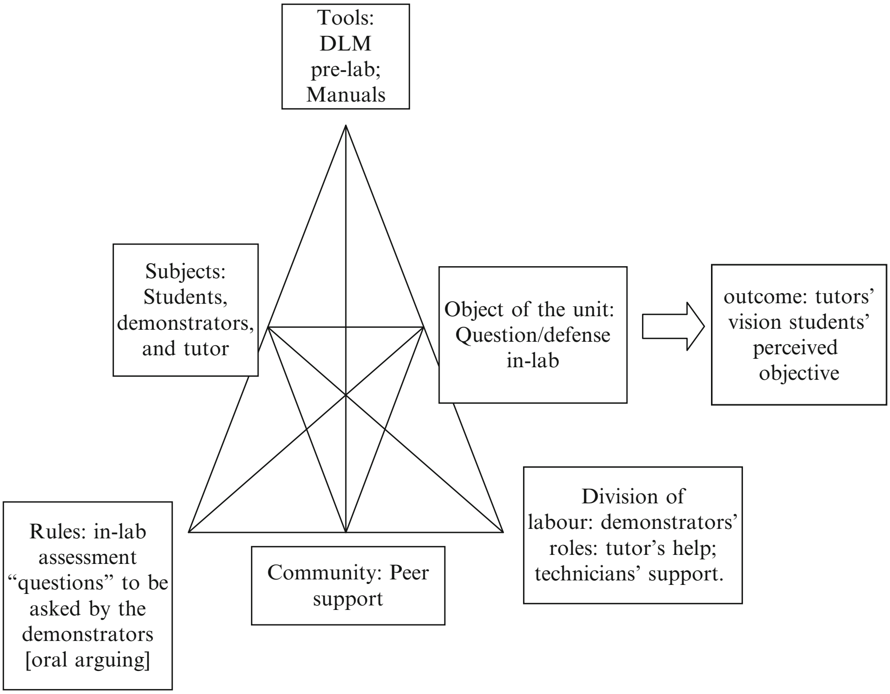


Fig. 16.1 Example of data analysis using Engestrom's triangle model

obtain insights and offers a flexible analysis unit to explore the issues of argumentation in tertiary chemistry practical course in both institutional and historical way.

In this study, the activity system as the basic analysis unit offers the methodological tool to explore the complexity of the learning environment; the focus on contradictions and historicity as a theoretical perspective directs the research to explore how the structure of the system mediates the learning; and the mediation nature of activity in CHAT helps to understand and analyze the role argumentation plays in the practical course. Moreover, CHAT also offers flexible analytical tools to tackle the complexity of the problem by sorting out the interacting activity systems and examining the underlying causes of the interest research topics. The analysis of data is focused on exploring the dynamics between instances of argumentation and this activity system (Fig. 16.1).

16.4 Methodology

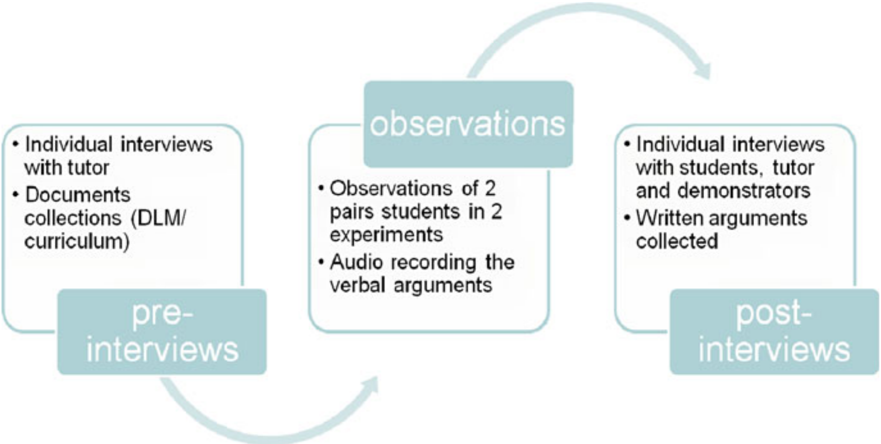
In light of both literature review and theoretical framework, this study has conducted a context-based qualitative study to explore the research questions, the case study as the methodology. With the focus on a small sample and specific case, rich data have been generated in order to pursue a deep understanding of the issues. Various data collection and analysis techniques have been used, as well as different information resources have been employed, in order to draw a holistic picture of the case, the activity system of the practical course.

16.4.1 Data Collection

This case study lasted for 10 weeks with the second year chemistry students in the laboratory from November 2011. Once a week students would conduct one experiment from 9 am to 5 pm. They have been divided into groups to take turns in doing 14 experiments in one academic term. The demonstrators worked in pairs and took turns to spend 4 h a day in the laboratory. They have been assigned to one to two experiments, according to their expertise, through the term. In the laboratory, there is a color-coding system to visualize the identity of the people in the laboratory: 2 technicians in blue coat, 1 demonstrator in orange coat for every 14–15 students who are in white coat, and 1 tutor in black coat for every 40–50 students. The students have been given instructions of the experiments both in hard copy and online environment (DLM). Before they can go into the laboratory, they have to pass a test in DLM regarding safety and basic information about experiments. During the experiments, the demonstrators will support the students and also evaluate the students' performance. They will question the students' understanding about the experiments as well. These in-lab assessments are part of the students' overall assessment. The students are also required to submit post-lab data analysis to the demonstrators. For certain experiments (6 out of 14 experiments in total), the students are required to write up an experiment report and submit it to tutors.

The following table illustrated how data was collected to address research questions. Before the observations in the laboratory had been done, the individual interviews have been conducted with the tutors who are in charge of this practical course. These semi-structured interviews provided the basic information about the routines of the practical course and also helped to focus the observations on the relevant topics. Then, observation, as a direct way to know the real situations in the complex context (Mason 2002), has also been used to immerse me into the field in order to obtain an understanding from the actor's perspective, as CHAT has required (Nardi 1996). The observations have been focused on two groups of students (there are four students in each group) recommended by the tutors. There were two sessions of experiments for each group that have been recorded. In particular, the interactions between the students and the demonstrators during the in-lab questioning session have been recorded as the oral arguments for further analysis. The individual interviews have been done with the students after the observations to explore whether their expectations of the practical course are relevant to argumentation and also their understanding of argumentation involved in the practical course. The students' experiment reports have also been collected as the examples of written arguments (Table 16.1).

Table 16.1 Data collection methods



16.4.2 Data Analysis

The research focus directs the choice of specific data analysis methods (Spencer et al. 2003). Two types of analysis have been used in this study: thematic analysis and structure analysis.

Thematic analysis has been used to draw the pictures of the learning environment of the case by identifying the themes from the transcriptions of both observations and interviews, and the curriculum and the department statements. The activity systems have firstly been identified according to the models of CHAT. The objects of the system and different subjects' orientations of argumentation have been identified. Then, the data have been further clustered around the moments defined by CHAT (such as tools, outcomes, rules, and distribution of labors) according to the activity systems. Particularly directed by the research literatures, the elements of argumentation have then been identified within the activity systems. The relationship between these argumentation elements and the rest of the activity systems has been explored. The initial themes emerged from these clustered data and modified during the repeated processes of data analysis.

The structure analysis has been applied to identify the features of argumentation through both the written arguments produced by the students and their discourse recorded in the laboratory. The choice of the analytical models of argumentation depends on specific disciplinary features and purpose of analysis (Clark et al. 2007). In this study, the Toulmin's model (TAP) has been adopted to look at the structures of the arguments. In particular, the focus has been put on exploring the discipline-specific features from "warrant" and "data."

In summary, the various data analysis techniques and specific models are being used to explore the research questions. In particular, guided by CHAT, the rich data is used to draw a holistic picture of the chemistry practical learning environment. The data analysis is focused on exploring the dynamics within this activity system regarding issues of argumentation.

16.5 The Initial Discussions

Several preliminary thoughts have been aroused during the coding of the data collected. Guided by CHAT, the relationships between identified argumentation and the rest of the systems have been particularly discussed.

16.5.1 Argumentation in the Laboratory

There are aspects of argumentation identified within the activity system. For example, in the rules of this activity system, the students are required to interpret the empirical data with relevant chemistry theories in their oral assessment in laboratory; and also they need to produce scientific arguments in their experiment reports. However, from the interviews of the participants, including the students, tutors, and demonstrators, the argumentation has been regarded as a means of communication to report interpretation and/or understanding. The students have acknowledged its importance in practices of science and also as a general skill for future work, while the tutors and the demonstrators have been explicitly focused on delivering the norms of scientific writing to students. All of the participants have been more aware of argumentation practices for experiment reports compared to oral discourse within the laboratories. Although the demonstrators used questions to test students' understanding of the experiments and many of them tried to guide the students to make connections between the phenomenon they observed in the laboratory and the chemistry theory they learned, few of them acknowledged these discussions as a tool for meaning making. Therefore, as for students' written arguments, there are more complete structures of argument as defined by Toulmin, while the students' oral arguments are in simpler forms. For example, the students would simply make claims without offering justifications during the discussions in the laboratory.

In summary, within the activity systems, argumentation has been identified as the objects, which the participants have been working on. Argumentation in this case has not been used as tool for acquiring the scientific knowledge as expected by the educators and researchers in the literature.

16.5.2 The Conflicting Management Rules and Educational Aims of the Course

In both the benchmark of the subject by QAA and the handbook for the practical, the elements of argumentation have been identified. However, the management rules of the practical course did not support the practices of argumentation. I argue that the students lack autonomous and authentic inquiry and are deprived of the space of argumentation. As literature of argumentation suggested, it requires space of arguing for participants taking part in meaningful argumentation process. But all the experiments of the practical have been carefully design to exemplify certain specific skills or techniques, instead of allowing the students to experience the process of scientific inquiry. During the experiments, the students have been busy finishing the experiment, preoccupied by the procedures and operations. For instance, they rarely had time to think and asked about why this specific technique is being used. The students didn't feel the necessity to argue.

There are also gaps between the tutors' education aim and the actual teaching methods. Although the tutors indeed think that the scientific inquiry is a necessary and essential part of the laboratory, they have complained that it is practically limited and full argumentation did not take place in the laboratory. Moreover, in the case of experiment reports, where the tutors have intended to explicitly teach the skills of scientific writing to the students, the students have not been fully satisfied with the guidance and the constructive feedback they've received. For instance, there were students who complained that the focus of guidance and feedback has been put on the format of writing instead of content. "I can change the font in 2 s, but it is what I am writing which matters," one girl said in the interview. By analyzing the guidance and feedback the students received, it seems that there is not enough explicitly epistemic understanding about scientific argumentation being addressed.

In summary, within the activity systems, the rules of the systems are in contradictions to objects and motivations. In other words, the way how the practical course is being organized is not in accordance with the aim of developing argumentation as required for the course.

16.5.3 The Participants' Different Orientations Toward the Course

The gaps identified within the activity systems as above are connected to the inconsistency between objects of the course and the expectations of the participants: the tutors tend to think that the aim of the teaching laboratory is mainly for equipping the students with basic experimental techniques and specific soft skills, such as time management. However, the students, on the other hand, are more likely to obtain the way of inquiry, including argumentation. The tutors are more focused on students' acquisition of certain skills and techniques, while the students are more expected to "understand the experiments," "understand the chemistry theory involved," and "understand why specific techniques been used in this experiment." For instance, one of the students interviewed expressed her concerns that she lacks confidence in conducting the experiments by herself, and also "I feel like I have been trained to be a technician instead of a chemist... I did not know much or think much about the design of the experiments".

This caused further gaps beyond the systems of this practical course. For instance, the students in their final year are required to conduct a research-based project, while the students lack the experiences of the process of scientific inquiry in the previous studies. The students also are concerned that, for their future career, no matter in research area or the industry, they would need to conduct and design experiments by themselves, while they feel they have not been prepared in the university. It seems, for tutors, the students have to acquire "the basic tool kit" of the experimental skills and techniques first, and then the students would be able to understand the nature of scientific inquiry gradually. This is in contradiction to the educators' expectations, which by conducting argumentation, the students would get access to the nature of the scientific inquiry through practicing the experimental skills.

16.6 Conclusions

This study explored the argumentation in specific discipline – chemistry and specific context – tertiary practical education, which extended the range of argumentation literature. Moreover, activity theory, as an evolving social cultural theory, has been adopted in this study and proved to be a useful theoretical framework to reveal the hidden contradictions in the complex learning environment. These contradictions indicate how the entangled factors, including the teachers, the tasks, the schooling systems, and the students, influence the arguments the students produced and the processes of arguing the students experienced.

Acknowledgement Thanks to my supervisors', Prof. Sibel Erduran and Dr. Federica Oliver, constructive suggestions and support all the way through.

References

Clark, D. B., Sampson, V., Weinberger, A., & Erkens, G. (2007). Analytic frameworks for assessing dialogic argumentation in online learning environments. *Educational Psychology Review, 19*(3), 343–374. doi:10.1007/s10648-007-9050-7.

Daniels, H. (2001). Current approaches to sociocultural and activity theory. In *Vygotsky and pedagogy*. London: Routledge/Farmer.

Driver, R., Newton, P., & Osborne, J. (2000). Establishing the norms of scientific argumentation in classrooms. *Science Education, 84*, 287–312.

Duschl, R., & Osborne, J. (2002). Supporting and promoting argumentation discourse. *Studies in Science Education, 38*, 39–72.

Erduran, S., Simon, S., & Osborne, J. (2004). TAPping into argumentation: Developments in the application of Toulmin's Argument Pattern for studying science discourse. *Science Education, 88*(6), 915–933. doi:10.1002/sce.20012.

Evagorou, M., & Avraamidou, L. (2008). The role of technology in supporting the process of argument construction in science learning. *Educational Media International, 45*(1), 33–45.

Jiménez-Aleixandre, M. P. (2008). Designing argumentation learning environments. In Erduran & Jiménez-Aleixandre (Eds.), *Argumentation in science education: Perspectives from classroom-based research*. Dordrecht: Springer.

Jiménez-Aleixandre, M. P., Bugallo Rodríguez, A., & Duschl, R. A. (2000). "Doing the lesson" or "doing science": Argument in high school genetics. *Science Education, 84*, 757–792.

Kuhn, D., & Udell, W. (2003). The development of argument skills. *Child Development, 74*(5), 1245–1260.

Langemeyer, I., & Nissen, M. (2005). Activity theory. In B. Somekh & C. Lewin (Eds.), *Research methods in the social sciences*. London: Sage.

Lawson, A. E. (2010). Basic inferences of scientific reasoning, argumentation, and discovery. *Science Education, 94*(2), 336–364.

Lee, M.-H., Wu, Y.-T., & Tsai, C.-C. (2009). Research trends in science education from 2003 to 2007: A content analysis of publications in selected journals. *International Journal of Science Education, 31*(15), 1999–2020.

Mason, J. (2002). *Qualitative researching* (2nd ed.). London: Sage.

Nardi, B. A. (1996). Studying context: A comparison of activity theory, situated action models and distributed cognition. In B. Nardi (Ed.), *Context and consciousness: Activity theory and human-computer interaction*. Cambridge, MA: MIT Press.

Osborne, J., Erduran, S., & Simon, S. (2004). Enhancing the quality of argumentation in school science. *Journal of Research in Science Teaching, 41*(10), 994–1020.

Roth, W.-M., & Lee, Y.-J. (2007). Vygotsky's neglected legacy: Cultural-historical activity theory. *Review of Educational Research, 77*(2), 186–232.

Sadler, T. D., & Donnelly, L. A. (2006). Socioscientific argumentation: The effects of content knowledge and morality. *International Journal of Science Education, 28*(12), 1463–1488.

Sandoval, W. A., & Millwood, K. A. (2008). What can argumentation tell us about epistemology? In S. Erduran & M. P. Jimenez-Aleixandre (Eds.), *Argumentation in science education* (pp. 71–88). Dordrecht: Springer.

Simon, S., Erduran, S., & Osborne, J. (2006). Learning to teach argumentation: Research and development in the science classroom. *International Journal of Science Education, 28*(2–3), 235–260.

Spencer, L., Ritchie, J., & O'connor, W. (2003). Analysis: Practices, principles and processes. In J. Ritchie & J. Lewis (Eds.), *Qualitative research practice: A guide for social science students and researchers*. London: Sage.

Zohar, A., & Nemet, F. (2002). Fostering students' knowledge and argumentation skills through dilemmas in human genetics. *Journal of Research in Science Teaching, 39*(1), 35–62.

Chapter 17
An Energy Education Curriculum for Children Based on Fostering Creativity in Elementary Schools

Rasool Abdullah Mirzaie and Neda Zerafatdoost

Abstract One of the concepts in science education in primary school is energy. Children are familiar with energy resources and consumption in everyday life. Some children's beliefs about energy are as follows: some things work with electricity; energy is necessary for the human body; without energy, one cannot do one's job; we eat food to obtain energy; there are many energy sources; and we must save our electrical energy by reducing consumption. In Iran, in the third year of elementary school onwards, the introduction of energy and resources and energy consumption is emphasized. In science education, various methods are used to involve students in the learning process. However, the way in which this significant subject is introduced to children is very important. To gain more understanding about the importance of energy and methods of consumption, this concept is taught in science class at third grade elementary school. For this purpose, we designed a science activity based on creativity. Fifty students were selected as participants. They were divided into control and experimental groups. This was applied research; the method was experimental and has been conducted with control and experimental groups with a pre-test and post-test. Measurement was carried out with Torrance's Test of Creative Thinking (TTCT, Figural form B) and an achievement test. The survey duration was 5 weeks. The experimental group was taught with practical activities and the control group was taught via traditional methods at the same time. We used descriptive and inferential statistical methods using SPSS software to analyze pre-test and post-test results. Our results showed a significant difference between the mean of pre- and post-tests for both the TTCT and the achievement test in the experimental group.

Keywords Science • Elementary school • Creativity • Third grade • Energy education curriculum

---

R.A. Mirzaie (✉) • N. Zerafatdoost
Department of Chemistry, Faculty of Science,
Shahid Rajaee Teacher Training University, Tehran, Iran
e-mail: ra.mirzaei@srttu.edu; mirzai_r@yahoo.com

B. Zhang et al. (eds.), *International Conference on Science Education 2012 Proceedings: Science Education: Policies and Social Responsibilities*,
DOI 10.1007/978-3-642-54365-4_17,

17.1 Introduction

Energy, which is essential for all forms of life, is a concept of daily life. This concept is used to express many variations of daily situations. For example, if someone is exhausted, he/she could say 'my energy is depleted'. In physics, the many variations in the way the word 'energy' is used can be summarized as the amount of work that can be performed by a force (Çoker et al. 2010).

Energy is an important idea in all branches of science, so you probably feel familiar with it whether your background is in physics, chemistry, or biology. You may think of energy as an idea that you understand, which should not therefore be too difficult to teach.

In fact it is much less straightforward than it appears, for two main reasons:

1. In science, energy is an abstract, mathematical idea. It is hard to define 'energy' or even to explain clearly what we mean by the word.
2. The word 'energy' is widely used in everyday contexts, including many that appear 'scientific' – but with a meaning that is less precise than its scientific meaning, and differs from it in certain respects.

The first means that, in order to communicate the scientific idea of energy to young learners, we have to simplify it – but still ensure that what we teach is clear and useful, and provides a sound basis for developing a fuller understanding later. The second means that we have to be very careful to disentangle the everyday usage of the word 'energy' from its scientific use, in order both to keep our own ideas clear and to avoid teaching pupils a potentially confusing mixture of the two (Milar 2005).

17.1.1 Why Education?

Ensuring all citizens are 'energy aware' is key, and the role of education and information initiatives in schools is crucial. Education has a strategic role in improving energy efficiency (Piebalgs 2006).

Studies in the last two decades have predicted that energy education will be a new discipline in both developed and developing countries. Therefore, developing countries in particular should take into account those studies and make some decisions about their energy, environment, and educational policies.

The need for energy education increases depending on war and economic turmoil day by day. What is important is to decide how energy education should be taught and what should be taught without such crises. However, the problem is that resources and studies on energy education are limited (Acikgoz 2010).

Each of us can make a profound difference by rising to the challenge and becoming more energy conscious in daily life. Beginning with primary school, educational initiatives at all levels can help raise awareness about this important issue.

Experience has shown that children and youngsters are key to achieving long-term behavioural changes in the rational use of energy and the use of renewable energy sources (Executive Agency for Competitiveness and Innovation Intelligent Energy 2009).

17.1.2 The Importance of Practical Activities in Energy Education

One of the most interesting results of recent research in cognitive science and science education is the realization that students and teachers hold strong misconceptions or alternative frameworks about many different science concepts (Trumper et al. 2000). Energy is one of those concepts.

Although renewable energy resources may be an important topic in school science, it should be taught carefully. Furthermore, they thought that students use a substantially more context-specific view. For this reason, in theoretical, context-free, and mainly quantitative teaching, their misconceptions and difficulties will continue to exist. On the other hand, it is hoped that context-rich scenarios and problems provide a setting and a confrontation with their thoughts to discuss different points of view and to apply their knowledge to practical situations so that they better comprehend the concepts of energy (Çoker et al. 2010).

Energy education has become an area of major importance for those responsible for school teaching. Teachers, politicians, and the public agree that school should equip students with the knowledge, skills, and abilities needed to live in a world faced with rising energy demands and shrinking energy resources (Trumper et al. 2000).

Hands-on and minds-on activities teaching and learning about the concept of energy in primary school are presented. The word ‘energy’, even if already used by the children in everyday life, is not mentioned by the teacher during the lessons of the didactic path so as to build the underlying concept on scientific bases, unfolding all the basic aspects and avoiding misconceptions and misunderstandings (Corni 2011).

17.1.3 What Is Practical Work?

Practical work is hands-on student activity that has become part of the tradition of science lessons in a number of countries over recent decades. Typically carried out in school laboratories, it involves students using equipment and making observations and inferences about real materials and how they behave. Practical work in science education is frequently seen to be a worthwhile aim, and developing favourable attitudes to science an important goal (Toplis 2012).

17.1.4 What Is Creativity?

Theories and ideas about creativity stem from far back in history, unsurprising as Ryhammer and Brolin (1999), point out, given that the development of new ideas and original products is a particularly human characteristic. The notion of ‘inspiration’ or ‘getting an idea’ (ibid, p. 260), is found in the Greek, Judaic, Christian and Muslim traditions and is founded on the belief that a higher power produces it. During the Romantic era in Europe, the source of inspiration and its artistic expression was seen as being the human being. During this era, originality, insight, the creative genius and the subjectivity of feeling were highly valued. From the end of the nineteenth century, people began to investigate the question of what fostered creativity (Abdullah Mirzaie et al. 2009).

17.2 Methodology

This research is considered an experimental design known as a pre- and post-test design with a control group. We selected a group of 9-year-old boys from one of Iran's primary schools and classified them into two groups of 25 students each, i.e. experimental and control groups. For both groups, a pre-test was first performed, with achievement and TTCT, and their results considered as basic achievement and creativity for both groups. In the next stage, science activities were performed for 4 weeks in the experimental group.

The purpose of this study was the introduction of energy resources (fossil fuels, water, wind, solar) and the effective use of energy to third-year students. Therefore, activities such as reading a story; colouring; expressing their understanding about these topics; and doing simple experimental activities were considered. After the last experiment, both groups were retested via the achievement test and TTCT.

In our study, science activity is considered an independent variable and achievement and creativity growth in children is considered a dependent variable. The analysis of the data was carried out using SPSS 18 software.

17.2.1 Study Group

Elementary school boys aged 9 years ($N = 50$) were selected as a statistical universe from one of Iran's cities in the 2011–2012 school years.

17.2.2 Instrument

17.2.2.1 Achievement Test

For the achievement test, 12 questions were designed based on the cognitive domain (Bloom's taxonomy). These questions were the same in both the pre-test and the post-test and concerned energy sources and energy consumption. The reliability of the test, calculated with Cronbach's alpha, was 0.79. The validity of the data gathering tool in the achievement test was confirmed by experienced teachers.

17.2.2.2 Torrance's Test of Creative Thinking

In this study, the figural form of the TTCT was used. A booklet was given to the students, containing three interesting things for the student to do. Each activity was allocated 10 min.

Activity 1: picture construction.
Activity 2: picture completion.
Activity 3: circles.

The students were asked to make their own picture by adding lines with pencil or crayon and to think up a name or title for it and write it at the bottom of the figure.

Torrance (1966, 1974) described four components by which individual creativity could be assessed:

Fluency: the ability to produce a large number of ideas.
Flexibility: the ability to produce a large variety of ideas.
Elaboration: the ability to develop, embellish, or fill out an idea.
Originality: the ability to produce ideas that are unusual, statistically infrequent, not banal or obvious (Torrance 1974).

The mean reliability coefficients for the figural tests were fluency 0.96, flexibility 0.94, originality 0.86, and elaboration 0.91 (Torrance 1974).

17.2.2.3 Simple Science Activities

In this work, we used practical activities for energy education that were simple and attractive to conduct in the experimental group. Students were divided into groups of 3 or 4.

The practical activity used to introduce fossil fuel resources was completion of a puzzle related to fossil fuel resources.

A simple activity was used to demonstrate water energy. Each group was given two identical plastic bottles and asked to do the following: fill one bottle with water and the other with pebbles until they are the same weight. Put the lids on both bottles and tighten. Students were asked, if they placed bottles on a slope and released them at the same time, which one will roll the furthest? Release both jars at the same time and observe. In doing this activity, students understand that, at first, the water-filled bottle moves down faster than the other one and the water-filled bottle begins to rotate more quickly. This happens because water has energy.

To demonstrate wind energy, students were directed to the school yard on a windy day. Pinwheels were given to each group. After a while, students observed the spinning of the pinwheels. They asked how pinwheels can spin without doing anything. After that, the wind blew more strongly and, at the same time, the pinwheels also began spinning more strongly. Students discovered that wind has energy and it causes pinwheels to spin. A picture of wind turbines was then shown to the students and some noted the similarities between pinwheels and wind turbines. Students then discussed wind energy with each other and with the teacher.

A simple experimental activity was used to demonstrate solar energy. Each group was given a different coloured glass and were asked to do the following: a representative of each group was asked to write the colour of the group's glass on the blackboard. The glasses were then filled with the same amount of cold water. The teacher helped the students record the temperature of the water, and each group wrote the temperature of the water on the blackboard. Students were asked to look at all temperatures. They noted that all glasses had the same temperature. Students were then asked to place all glasses in a sunny place for 1 h. After 1 h, students were asked to record the temperature of the water again and write the second temperature on the blackboard too. Students noted that all temperatures had increased, but that they were not the same. After a while, students expressed that, because of sun energy, water is heated and the glasses that are dark had absorbed more solar energy.

For consumption of energy, students were given a story about energy consumption; after reading the story, students were asked to express what they learned. Colouring sheets were then given to students and they were asked to find energy savers and energy wasters in the picture and write them down.

The control group was taught with traditional methods at the same time.

17.3 Results

For studying hypothesis with regard to variable nature, the *t*-test is used as one of the statistical inferential methods for comparison of the pre- and post-test results. As the significance level, $\alpha = 0.05$ is used ($p < 0.05$). For facilitating analysis of data and decreasing statistical error, Microsoft® Excel and SPSS software were used. Descriptive indices of this research included average and standard deviation of the scores in the pre- and post-tests (Tables 17.1 and 17.2).

Table 17.1 Pre- and post-test descriptive data from the achievement test in experimental and control groups

		Achievement	
Test	Group	Mean	Standard deviation
Pre-test	Control	116.58	29.76
	Experimental	118.01	32.51
Post-test	Control	121.54	26.62
	Experimental	151.66	26.98

Table 17.2 Mean standard deviation and result of independent *t*-test for comparison difference achievement scores between experiment and control groups

Test	Mean difference	Standard error difference	*t*	df	Significance
Pre-test	1.43	8.81	0.162	48	0.87
Post-test	30.12	7.58	3.97	48	0.00

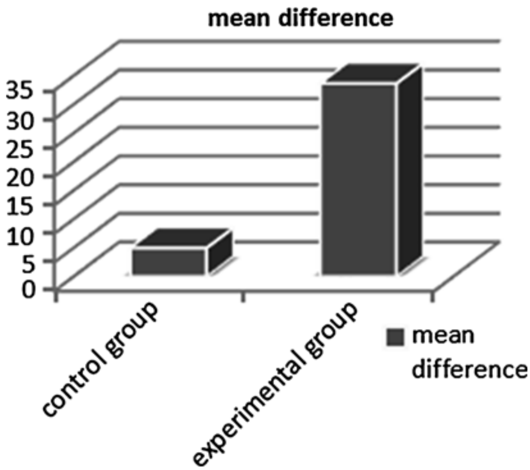


Fig. 17.1 Pre- and post-test comparison achievement test results between experimental and control groups

Table 17.3 Pre- and post-test descriptive data for Torrance's Test of Creative thinking in experimental and control groups

		Fluency		Flexibility		Originality		Elaboration	
Test	Group	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Pre-test	Control	19.52	1.45	15.84	2.30	19.04	7.01	56.72	12.05
	Experimental	20.20	3.15	16.36	2.77	19.24	5.58	56.96	10.37
Post-test	Control	19.60	1.89	16.20	1.98	19.92	5.96	57.16	13.72
	Experimental	24.20	2.83	19.80	2.69	31.16	8.26	92.16	18.25

SD standard deviation

Pre- and post-test achievement scores are calculated in experimental and control groups individually. Subtraction between obtained scores in the mentioned groups are then worked out separately. As shown in Table 17.2 and Fig. 17.1, the *t*-test showed that the differences between the experimental and control groups in the achievement test are significant.

The *t*-test is applied to find a significant difference between the averages of the groups pre-test and post-test. The findings suggest significant statistical differences for the achievement test (t (48) = 3.97; $p < 0.05$) (Table 17.3).

Pre- and post-test dimensions of TTCT scores are calculated in experimental and control groups individually. Subtraction between obtained scores in mentioned groups are then worked out separately. As shown in Table 17.4 and Fig. 17.2, the *t*-test showed that the differences between the experimental and the control group in dimensions of TTCT are significant.

The *t*-test is applied in order to find a significant difference between the averages of the groups which they have received pre-test and post-test. The findings suggested significant statistical differences for the dimensions of fluency (t (48) = 6.76; $p < 0.05$), flexibility (t (48) = 5.39; $p < 0.05$) originality (t (48) = 5.52; $p < 0.05$) and elaboration (t (48) = 7.66; $p < 0.05$).

Table 17.4 Mean standard deviation and result of independent *t*-test for comparison difference scores between experiment and control groups

Dimension	Test	Mean difference	Standard error difference	*t*	df	Significance
Fluency	Pre-test	0.68	0.69	0.98	48	0.33
	Post-test	4.60	0.68	6.76	48	0.00
Flexibility	Pre-test	0.52	0.72	0.72	48	0.30
	Post-test	3.60	0.67	5.39	48	0.00
Originality	Pre-test	0.20	1.79	0.11	48	0.18
	Post-test	11.24	2.04	5.52	48	0.00
Elaboration	Pre-test	0.24	3.18	0.075	48	0.94
	Post-test	35.00	4.57	7.66	48	0.00

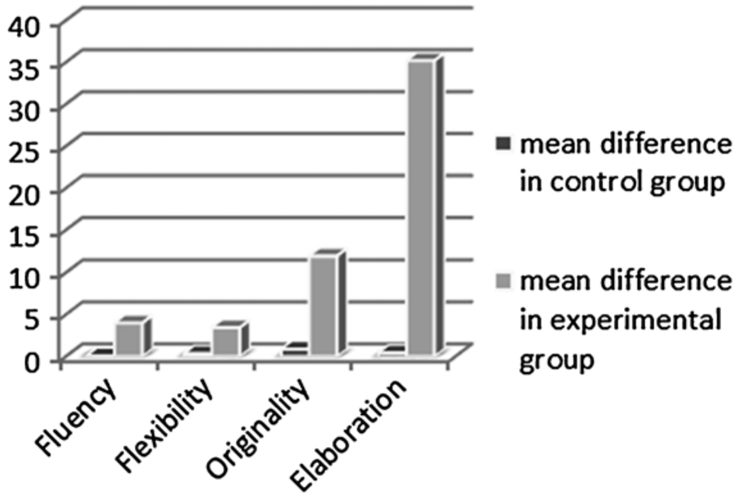


Fig. 17.2 Pre- and post-test comparison Torrance's Test of Creative Thinking test results between the experimental and the control group

17.4 Conclusions

This study investigated the effect of practical activities in science education on learning and creativity of male third-year elementary school students. According our findings, using practical activities as a teaching method increases learning and creativity in children. This method provides a suitable environment for free expression of ideas without any hesitation and criticism. These conditions mean psychic security for the learner. These situations result in the expression of new ideas with more detail by learners. Therefore, this teaching method affects creativity by elaboration item in the TTCT. On the other hand, in this state, learners express their ideas without limitations. With an increasing number of learner's ideas, fluency as one of the creative thinking factors would be developed. Expression of more ideas will tend to produce suitable and more various ideas by doing science activities.

According to present research findings and Harlen (1997), simple practical science activities can be used to foster creativity in children, so they should perform these activities as group work. Harlen (1997) proposed that materials can be given to children so they discover information about them by employing experience and inference. It is the best way to help children understand their environment. According to the present investigation, involving children in practical activities for science education is going to enhance creativity. Therefore, we advise that simple science activities be included in elementary school curricula.

The findings of these studies showed that students in the experimental group had higher results in learning and creativity than those in the control group. It is thought that this is the result of using practical activities. The results of this study showed the effectiveness of introduced teaching patterns for learning energy concepts in elementary school.

References

Abdullah Mirzaie, R., Hamidi, F., & Anaraki, A. (2009). Study on the effect of science activities on fostering creativity in preschool children. *Journal of Turkish Science Education, 6*(3).

Acikgoz, C. (2010). Renewable energy education in Turkey. *Renewable Energy, 36*(2), 608–611.

Çoker, B., Çatlioğlu, H., & Birgin, O. (2010). Conceptions of students about renewable energy sources: A need to teach based on contextual approaches. *Procedia Social and Behavioral Sciences, 2*(2), 1488–1492.

Corni, F. (2011). An approach to the concept of energy for primary school: Disciplinary framework, elements of a didactic path and assessment scale. SEENET-MTP seminar for teachers trends in modern physics.

Executive Agency for Competitiveness and Innovation Intelligent Energy. (2009). *Energy education, changing their habits in our lifetime*. Luxembourg: Publications Office of the European Union.

Harlen, W. (1997). Primary teachers' understanding in science and its impact in the classroom. *Research in Science Education, 27*(3), 323–337.

Milar, R. (2005). *Teaching about energy*. York: Department of Educational Studies, The University of York.

Piebalgs, A. (2006). *Education on energy: Teaching tomorrow's energy consumers*. Luxembourg: European Commission.

Ryhammar, L., & Brolin, C. (1999). Creativity research: Historical considerations and main lines of development. *Scandinavian Journal of Educational Research, 43*(3), 259–273.

Toplis, R. (2012). Students' views about secondary school science lessons: The role of practical work. *Research in Science Education, 42*, 531–549.

Torrance, E. P. (1966). *Torrance tests of creative thinking: Norms-technical manual* (Research ed.). Princeton: Personnel Press.

Torrance, E. P. (1974). Torrance test of creative thinking. Direction manual scoring guide, Figural test booklet. Published by personnel press (A division of Ginn and Company).

Trumper, R., Raviolo, A., & Shnersch, A. M. (2000). A cross-cultural survey of conceptions of energy among elementary school teachers in training – Empirical results from Israel and Argentina. *Teaching Teacher Education, 16*, 697–714.

Chapter 18
Effects of Different Contexts on Lower Secondary School Students' Scientific Reasoning

Hiroshi Unzai

Abstract This study aimed to explore the relationship between the thinking process in scientific reasoning and contexts among Japanese lower secondary students. As a result, it was found that the process of scientific thinking varied according to contexts.

Keywords Scientific reasoning • Lower secondary • Context • Japanese student

18.1 Introduction

Reasoning skills are major contributors to academic and everyday life success (Zeineddin and Abd-El-Khalick 2010). As a consequence, the development of students' scientific reasoning skills is one of the goals of science education in Japan (MEXT 2008). This study focuses on the three phases of reasoning and the two contexts of text when we investigate the scientific reasoning skills of Japanese lower secondary school students. We defined the meaning of scientific reasoning as "derive the law and nature of natural events (conclusions) from several experimental results (premises)." Based on this definition and processes of thinking (Kadoya 2011), scientific reasoning may be considered to have three phases: choose premises (phase 1), derive conclusions (phase 2), and consider the processes of thought (phase 3). In addition, two forms of context may be considered, they are graphs and tables in the text because experimental results of science are often showed in a graph or table form.

This study aimed to explore the relationship between the process of thinking in scientific reasoning and contexts among Japanese lower secondary students.

H. Unzai (✉)
Graduate School of Education, Hiroshima University, Hiroshima, Japan
e-mail: hiroshi-unzai@hiroshima-u.ac.jp

B. Zhang et al. (eds.), *International Conference on Science Education 2012 Proceedings: Science Education: Policies and Social Responsibilities*,
DOI 10.1007/978-3-642-54365-4_18,

Table 18.1 Participant's scores

Phase	Mean	Form of text	Mean
Phase 1	5.93	Table	2.80
		Graph	3.13
Phase 2	5.12	Table	2.84
		Graph	2.28
Phase 3	4.18	Table	2.13
		Graph	2.05

18.2 Results and Discussion

In order to explore that relationship, we created a questionnaire that consisted of four questions including three phases in each. Two questions were on the content of tables, and other questions were on the content of graphs. The questionnaire was administered to 271 Japanese students. Table 18.1 presents participant's scores on the questionnaire. To explore the differences between the three phases in two contexts, the mean scores of each were analyzed by ANOVA and Bonferroni multiple comparison test. This analysis revealed the following: (a) the mean score in the table context was lower than that in the graph context at phase 1 ($p<0.05$), (b) the mean score in the table context is higher than that in the graph context at phase 2 ($p<0.05$), and (c) there was no difference between the contexts at phase 3.

Phase 1 was about putting experimental results together for the conclusion. The table context provides more complexity of comparison between variables than the graph context. Phase 2 was about deriving the conclusion from experimental results. The table context provides more clear viewpoints than the graph context. Phase 3 was about considering the process of thought. There was no difference between the contexts at phase 3 because students did not consider the process of thought when they learn science. Based on the results of this analysis, teachers need to prepare the complex context in science lessons to enhance his/her scientific reasoning skills.

References

Kadoya, S. (2011). *Atarashii-Manabi-wo-Hiraku-Rikajyugyou-no-Riron-to-Jissen Syougakkouhen (in Japanese)*. Kyoto: Minerva Publishing.

MEXT. (2008). *The course of study for junior high school (in Japanese)*. Kyoto: Higashiyama Publishing.

Zeineddin, A., & Abd-el-khalick, F. (2010). Scientific reasoning and epistemological commitments: Coordination of theory and evidence among college science students. *Journal of Research in Science Teaching, 47*(9), 1064–1093.

Chapter 19
Exploration of High School Students' Concepts About Climate Change Through the Use of an Issue Concept Map (IC-Map)

Kongju Mun, Jinhee Kim, Sung-Won Kim, and Joseph Krajcik

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) which is a structured concept map 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 at personal, societal, and global levels. 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 about climate change that could be put into 63 categories. Based on the results, 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 also allowed students to express their ideas and make connections between concepts. IC-map can be an effective tool for examine students' scientific concept understanding.

Keywords Climate change • Concept map • Issue concept map • Global warming • Concept understanding

K. Mun (✉) • J. Kim • S.-W. Kim
Ewha Womans University, Seoul, Republic of Korea
e-mail: mkj@ewha.ac.kr; kkjjeneb@hotmail.com; sungwon@ewha.ac.kr

J. Krajcik
Michigan State University, East Lansing, MI, USA
e-mail: krajcik@msu.edu

B. Zhang et al. (eds.), *International Conference on Science Education 2012 Proceedings: Science Education: Policies and Social Responsibilities*,
DOI 10.1007/978-3-642-54365-4_19,

19.1 Introduction

The Intergovernmental Panel on Climate Change (IPCC) links climate change to human behaviors, particularly the use of fossil fuels. "Global Greenhouse Gas emissions due to human activities have grown since pre-industrial time, with an increase of 70 % between 1970 and 2004" (IPCC 2007, p. 4). Increasing average temperatures, rising sea levels, desertification, shifting of ecological cycles, and increased occurrences of extreme weather phenomena such as cyclones are now considered to be explicit evidence of climate change (IPCC 2007).

Global climate change is increasing the urgent need for effective educational materials that deal with science and the human and behavioral dimensions of climate change. Science and environmental education researchers have emphasized that climate change should primarily be a topic for secondary education students (Aydin 2010; Boon 2010; Mintz 2006). A conceptual understanding of climate change is crucial because students' scientific knowledge influences their environmental behavior (Dijkstra and Goedhart 2012).

Many researchers have tried to assess students' knowledge and attitude with regard to issues related to climate change, such as the greenhouse effect and ozone layer depletion (Boyes and Stanisstreet 1997; Dove 1996; Francis et al. 1993; Rye et al. 1997). These researchers investigated students' and teachers' perceptions and attitudes on climate change. They also examined educational programs dealing with climate change, and they analyzed the content of various textbooks.

Although information on climate change is now freely accessible in this highly technological society, a lack of public understanding of the issues of climate change and opportunities for effective responses still persists (Leiserowitz 2003; Leiserowitz and Smith 2010; Leiserowitz et al. 2007; Patchen 2006; Pew Research Center for the People and the Press 2007, 2009). The national curriculum in Korea includes climate change as an important concept for students. Many Korean citizens, however, particularly secondary school students, have demonstrated a lack of understanding of climate change (ME 2008).

The public's limited understanding of climate change is due in part to the slow-paced development and delivery of effective climate change education (NRC 2007). From this research, we found that misunderstandings regarding climate change still remain. Over the past 15 years, researchers have proven that the essential science of climate change is innately difficult for most learners to follow (Boyes and Stanisstreet 1993, 1997, 2001; Coyle 2005). Scientific knowledge about climate change is not an easy subject for science educators to teach (Abbasi 2006; National Research Council 2007; Storksdieck 2006). Furthermore, climate change has become a highly politicized topic in the policy arena and in the field of education, and people's willingness to be educated or to learn depends on their attitude toward the issue itself (Gardner and Stern 2008; Leiserowitz and Smith 2010). As a result, occasional political controversies have arisen (Hulme 2009). These educational and political issues have made it unfeasible to use traditional approaches to teach the subject of climate change (Center for Research on Environmental Decisions [CRED] 2009; Pruneau et al. 2010). Climate change is a complex social and physical phenomenon, and it has a high degree of temporal and spatial variability (IPCC 2007; Parmesan 2006; Philander 2008).

Recently, science education and environmental education have become increasingly integrated (Dijkstra and Goedhart 2012). Science educators in the twenty-first century put a special emphasis on students' integrated understanding of scientific core ideas (NRC 2007; Smith et al. 2006; Stevens et al. 2009). Climate change represents an integrated concept that encompasses scientific content, an environmental perspective, a social context, and even issues of economics and policy. In order to understand this kind of integrated knowledge, students should develop the ability to solve complex problems in personal, societal, and global contexts by collaborating and communicating with others (AAAS 2007; NRC 2007).

Most previous researchers used multiple choice tests or short answer questions. These kinds of instruments provided limited information on students' conceptual understanding (Boyes and Stanisstreet 1997; Andersson and Wallin 2000; Boon 2010). Concept maps, open-ended questions, and individual interviews are recommended to investigate students' perception and thought (Brody et al. 1989). To assess students' knowledge about climate change, we developed a guided concept map that can help students to easily express their ideas in the classroom. We called this map an issue concept map (IC-map). According to previous research, climate change is considered to be a socio-scientific issue that has personal, societal, and global implications (Choi et al. 2012; Lee et al. 2012). With that in mind, we organized our IC-map into three contexts (personal, societal, and global) and three occurrences (cause, influence, and countermeasure). Researchers have emphasized that behavioral response to climate change ranges from broad societal action to smart energy choices on a household level (Gardner and Stern 2008). Furthermore, the complexities of climate change have led some researchers to suggest that students should understand the causes, influences, and countermeasures of climate change (Morgan and Moran 1995; Dove 1996).

In this study, we tried to determine high school students' understanding of climate change through use of an IC-map. Our research questions were as follows:

First, how much do the students know or understand with regard to the concepts of climate change?

Second, what are some of the misunderstandings and misconceptions among the students regarding climate change?

Third, what types of connections can we find among the three contexts and three occurrences using the IC-map?

19.2 Methods

19.2.1 Participants

A total of 155 Korean tenth-grade students participated in this study (94 female and 61 male). We collected data from two high schools in Seoul. All of the participants were enrolled in the required science course and had learned about the carbon cycle

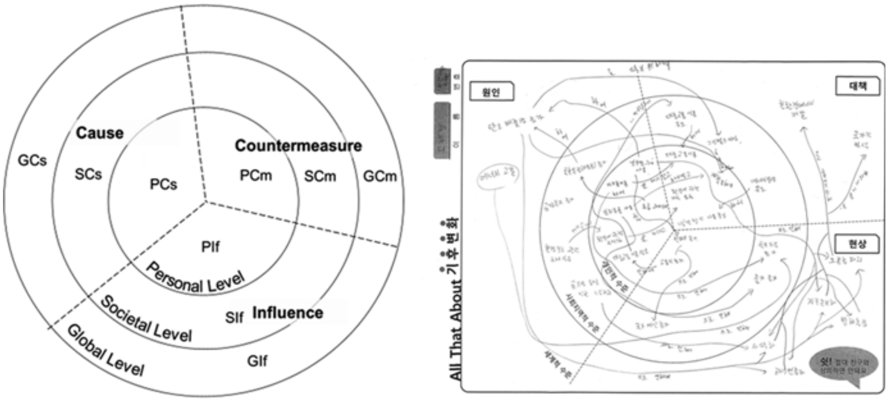


Fig. 19.1 IC-map worksheet and students' example

and climate change from the unit "Energy and Environment" which is included in the National Science Curriculum (MEST 2009).

19.2.2 Instrument: Issue Concept Map (IC-Map)

Concept mapping can be helpful in promoting an understanding of which new material interacts with the students' existing cognitive structure. The structure of a concept map reflects their experiences, beliefs, and biases, as well as an understanding of topic. The instrument we developed was on the basis of the ideas of Novak and Gowin (1984), and additional directions were added to provide scaffolding to express and to extend the students' thought and perceptions. The accompanying worksheet is organized into nine cells divided by three contexts (personal, societal, and global) and three occurrences (cause, influence, and countermeasure). Figure 19.1 shows the IC-map worksheet and abbreviations for the nine cells (e.g., Personal Cause = PCs, Global Influence = GIf). The IC-map allowed students to consider the causes, influences, and countermeasures of climate change on a personal, societal, and global level. The IC-map also allowed each student to freely express his or her own ideas and concepts regarding climate change.

19.2.3 Data Collection and Analysis

The science teacher who participated in this study explained how to draw and complete the IC-map and gave an example to the students before the start of the activity. Students completed their IC-map worksheets individually to express what they knew about climate. Figure 19.1 provides an example of the students' IC-map worksheet on climate change. Students could freely express their ideas, thoughts, knowledge, and attitudes about climate change on the IC-map. It took almost 50 min to complete the activity. Three science education researchers coded and categorized the students' words or sentences. They continued to discuss the data until they reached a consensus on the results. First, we coded all 3,570 students' words or sentences using 1–224 code numbers, and those contexts and occurrences were also coded using an Excel spread sheet. Each code number indicated a particular concept of the students' understanding regarding climate change. Sentences that had similar meanings were given the same concept code. For example, code number 142 indicated "use of car." The concepts "use of private car" and "use of an owner-driven car" were given the same code number of 142. Secondly, we classified 224 concepts into 63 categories. For example, "increase of carbon dioxide emission," "Freon gas emission," and "methane gas emission" were all categorized as "greenhouse gas emission." Thirdly, we analyzed and identified patterns on the basis of the connections among concepts on the students' IC-map.

19.3 Results and Discussion

From the students' worksheets, we explored what students understand or misunderstand about climate change. In addition, trends of connections between concepts emerged through investigating the students' answers on their IC-maps.

19.3.1 Students' Concepts About Climate Change

The total number of student answers on the IC-map was 3,570, with the average for an individual student of around 24. There were 290–724 answers written in each cell. We identified 224 concepts on climate change from the students' answers. Those were able to be separated into 63 categories (see Tables 19.2, 19.3, and 19.4). The global influence (GIf) cell represents the highest number of students' answers. There were 724 answers presented in the GIf cell, and we summarized the number of answers for nine cells in Table 19.1. From these results, we made the following assumptions with regard to the students' understanding of climate change: (1) they know more about causes and countermeasure on a personal level, and (2) they know more about influence on a global level. The students thought that personal behaviors such as "overuse of electricity" and "use of disposable products" have an impact on climate change and that climate change is a global phenomenon.

Some of the concept categories (e.g., greenhouse gas emission) were placed in more than one cell. Table 19.2 shows the students' concept categories for the causes of climate change. Most of the students thought that "energy waste," "trash

Table 19.1 Number of students' answers in each of the nine cells

Context level	Personal (P)	Societal (S)	Global (G)	Total
Cause (Cs)	469	351	302	1,122
Influence (If)	319	393	724	1,436
Countermeasure (Cm)	404	318	290	1,012
Total	1,192	1,062	1,316	3,570

Table 19.2 Concept categories for *cause* of climate change by context level (number of students' answers)

Personal	Societal	Global
Energy waste (232)	Industrialization (76)	Energy exhaustion (52)
Trash incineration (93)	Environment pollution (37)	Greenhouse gas emission (45)
Greenhouse gas emission (37)	Deforestation (35)	Deforestation (30)
Eating habit mainly with meat (16)	Excessive development (27)	Global warming (27)
Environment pollution (15)	Energy waste (22)	Industrialization (22)
Resources waste (14)	Government controls (20)	Excessive development (19)
Water pollution (10)	Trash incineration (17)	Rainforests destruction (13)
Energy exhaustion (9)	Energy exhaustion (16)	Energy waste (9)
Consumption culture (8)	Greenhouse gas emission (15)	Overexploitation (7)
Little understanding (8)	Rising livestock industry (15)	Environment pollution (7)
	Urbanization/population growth (14)	Abnormal climate (6)
	Lack of understanding (12)	Climate change (5)
		Urbanization/population growth (5)
		Ecosystem problem (5)

Note. We listed concept categories in descending order based on the number of students' answers

incineration," and "greenhouse gas emission" are all causes of climate change on a personal context level. "Eating habit mainly with meat," "environmental pollution," "resources waste," etc., were also considered by the students to be personal causes (PCs). The "energy waste" category indicates fossil fuel use such as "over use of gas," "over use of air-conditioning or radiator," and "use of electricity."

Students used the terms "greenhouse gas," "carbon dioxide," "methane," and "Freon." They considered greenhouse gas emission to be a major cause of climate change on a personal, societal, and global level. However, they considered "trash incineration" to be personal and societal behavior. The "trash incineration" concept category involves "no use of recycling bin," "use of disposable products," "food waste," etc., and those are all related to personal behavior in everyday life. These personal behaviors can extend to societal and global problems. Students also connected their ideas about personal causes to societal problems such as "industrialization," "environment pollution," and "deforestation." Societal and global contexts show similar concept categories. "Energy exhaustion," "greenhouse gas emission," and "deforestation" occurred most frequently in the students' global cause cell. From these results, we determined that students considered greenhouse gas to be a main cause of climate change.

Table 19.3 Concept categories for *influence* of climate change on a context level (number of students' answers)

Personal	Societal	Global
Rising gas price (88)	Rising gas price (59)	Sea-level rising (130)
Disease (38)	Natural disaster (49)	Abnormal climate (109)
Abnormal climate (32)	Abnormal climate (40)	Global warming (98)
Energy waste (22)	Ecosystem problem (32)	Ecosystem problem (56)
Environment pollution (22)	Greenhouse gas emission (25)	Deforestation (53)
Greenhouse gas emission (21)	Environment pollution (25)	Natural disaster (38)
Global warming (21)	Deforestation (21)	Ozone layer depletion (37)
Natural disaster (15)	Global warming (19)	Greenhouse gas emission (33)
Garbage inflation (11)	Rising sea level (17)	War/terror (23)
Ecosystem problem (7)	Urban heat island (15)	Rising gas price (17)
	National budget increase (12)	Environment pollution (15)
	Disease (8), Energy exhaustion (7)	Disease (11)
	Trash incineration (6)	Climate refugee (10)
	Energy waste (6)	Climate Change (9)
		Famine (8), Water shortage (8)
		Dispute between nations (7)
		Rich-poor gap (7)
		UV rays increase (5)

Note. We listed concept categories in descending order based on the number of students' answers

The most frequent answer for the influence of climate change was "sea-level rising" in the global context (Gif = 130), and the second highest number of answers related to "rising gas price" (PIf = 88, SIf = 59, Gif = 17). Influence of climate change in a personal context was indicated with "disease," "abnormal climate," "energy waste," etc. Students answers reveal "natural disaster," "abnormal climate," and "ecosystem problem" as social influences and "sea-level rising," "abnormal climate," and "global warming" as global influences (Gif). On the basis of the students' IC-map, we found that students' understand the influence of climate change on a global context level. The students thought that main influences of climate change are "sea-level rising" and "global warming." Many answers in the global influence cell were related to global warming (Table 19.3).

Students' answers in the countermeasure cells were about how to limit personal behavior that causes climate change. For example, students' indicated "energy conservation," "trash reduction," "planting," and "eco-friendly development" in the personal countermeasure cell. They also suggested certain societal efforts for preventing climate change, such as "government controls," "campaign," and "environment education." The global countermeasure cell showed similar answers to those in the societal countermeasure cell. Students suggested that the most effective measure is "international collaboration" following by "renewable energy" and "eco-friendly development." Papadimitriou (2004) found similar results from students' responses to the question of how to alleviate climate change; they mentioned participating in

Table 19.4 Concept categories for *countermeasure* of climate change by context level (number of students' answers)

Personal	Societal	Global
Energy conservation (232)	Energy conservation (57)	International collaboration (90)
Trash reduction (65)	Government controls (42)	Renewable energy (75)
Planting (17)	Eco-friendly development (36)	Planting (16)
Eco-friendly development (15)	Campaign (25)	Carbon reduction (14)
Meat diet reduction (11)	Renewable energy (24)	Government controls (12)
Water saving (7)	Planting (23)	Eco-friendly development (15)
Resource saving (6)	Carbon reduction (23)	Energy conservation (9)
Environment education (6)	Trash reduction (11)	Technical development (7)
Campaign (5)	Technical development (7)	Tropical forests protection (7) Campaign (7)
	Meat diet reduction (5)	
	Environment education (7)	
	International collaboration (5)	

Note. We listed concept categories in descending order based on the number of students' answers

environmental groups, raising people's awareness and responsibility, planting trees, using alternative energy, reducing the use of cars, and so on. Some of the students' answers in concept categories such as "trash reduction," "eco-friendly development," and "meat diet reduction" are not proper countermeasures for climate change (Papadimitriou 2004). Some students connected their answer related to "greenhouse gas emission" in the cause or influence cells to the answer in the countermeasure cells. On the basis of these results, we found that high school students can understand why these suggestions, which they responded to in the countermeasure cells, are helpful for greenhouse gas reduction. This is quite different from primary students, who did not understand why they should try to increase efforts in recycling, using of eco-friendly products (Papadimitriou 2004) (Table 19.4).

19.3.2 Misunderstandings and Misconceptions About Climate Change

Many researchers found that students were confusing climate change with other environmental problems such as ozone layer depletion and greenhouse gas emission (Anderson and Wallin 2000; Boyes and Stanisstreet 1997). In particular, students confused climate change with global warming. A study of seventh-grade American students has shown that students lack a rich conceptualization with respect to the vocabulary of climate change and global warming (Shepardson et al. 2009). Public debates also use these terms interchangeably (Schuldt et al. 2011). We also found evidence of the same problems in the present study. Table 19.5 shows students answers related to greenhouse gases. The total number of students' answers related to greenhouse gas emission was 170, including carbon dioxide gas (49 %), the greenhouse effect (15 %), methane gas (13 %), and Freon gas (23 %). From the total number of students' answers related to greenhouse gas emission, 93 students wrote

Table 19.5 Students' answers related to emission of greenhouse gases

	Cause			Influence			
Category	Personal	Societal	Global	Personal	Societal	Global	Total
Carbon dioxide gas	3	8	26	12	13	22	84
Greenhouse gas	–	2	10	3	4	6	25
Methane gas	2	2	5	4	5	4	22
Freon gas (CFC)	31	–	4	2	2	–	39
Total	93			77			170

Table 19.6 Students' answers related to ozone layer depletion

	Cause			Influence			
Concepts	Personal	Societal	Global	Personal	Societal	Global	Total
Hairspray use	23	–	–	–	–	–	23
CFC (Freon gas)	31	–	4	2	2	–	39
Rising UV rays	–	–	–	1	1	5	7
Ozone layer depletion	–	3	7	2	4	37	53
Total	31	3	11	5	7	42	99

their response in the cause cells and 77 students wrote in the influence cells. These results show that students consider greenhouse gas to be not only a cause of climate change but also an influence of climate change.

We also found that many students answered about "ozone layer depletion" on the climate change IC-map. Table 19.6 shows the number of students' answers related to ozone layer depletion. Students responded "hairspray use," "Freon gas" influencing "ozone layer depletion," and "rising UV rays," and these concepts related to ozone layer depletion resulted in global warming. In other words, students thought the holes in the ozone layer were made worse by the greenhouse effect, which caused an increase in the average Earth temperature. These results showed that students had a general merged thinking about global warming and ozone layer depletion (Boon 2010). Students may associate their ideas that global warming is caused by increased penetration of solar radiation with the notion that ozone layer holes can result in an increased amount of solar radiation to the Earth (Kerr and Walz 2007; Schreiner et al. 2005). This kind of assumption is somewhat reasonable because of the complexity of the science of climate change. Because of this complexity, which necessitates personal attention and results in controversy, students had difficulty understanding the conceptualization of climate change and global warming exactly (Shepardson et al. 2009).

19.3.3 Trends of Connections Between Concepts

From the students' IC-map activities, two trends emerged on the basis of the connections between concepts. First, students draw connections from a personal context to societal and global contexts. We explored students' conceptions of climate change

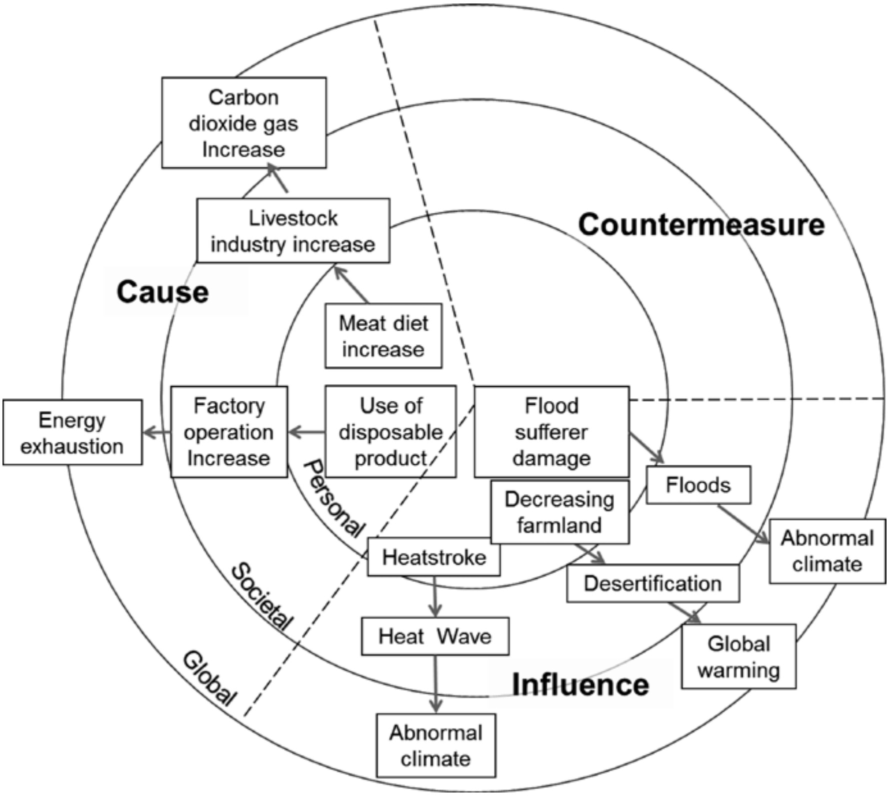


Fig. 19.2 Personal-societal-global connection

on the basis of personal-societal-global context. Students connected their answers when they completed the IC-map, so that they extended their conceptions from personal to societal and global contexts in the cause, influence, and occurrence cells. For example, the conceptions of "meat diet increase" in the personal cause (PCs) cell linked to the conceptions of "livestock industry increase" in the societal cause (SCs) cell and "carbon dioxide increase" in the global cause (GCs) cell. Other examples of this personal-societal-global connection are "decrease in farmland" in a personal context connected to "desertification" in a societal context and "global warming" in a global context. Figure 19.2 shows examples of students' personal-societal-global connections.

Second, students drew connections from cause to effect and countermeasure. Students linked cause and influence, and then they subsequently presented solutions in countermeasure. Students came up with ideas and solutions for reducing climate change in the countermeasure cell upon considering the cause and influence of climate change. We found that the majority of students drew cause-influence-countermeasure connections as shown in Fig. 19.3. When a student completes the IC-map worksheet, for example, he/she writes "excessive air-conditioner" in the

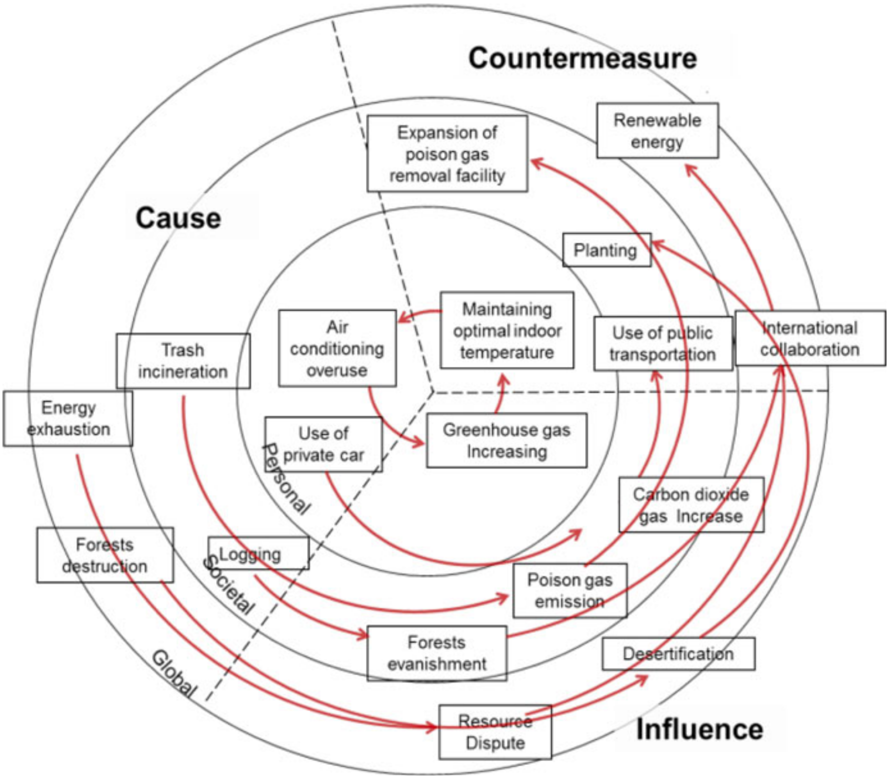


Fig. 19.3 Cause-influence-countermeasure connection

personal cause (PCs) first, and then he/she thinks about what is the result of it. Next, he/she writes "greenhouse gas increasing" in the personal influence (PIf) and "maintaining optimal indoor temperature" in the personal countermeasure (PCm) and then draws a link within. We also found that a cause-influence-countermeasure connection not on the same context level, "logging" the social cause (SCs), "forests evanishment" in social influence (SIf), and "international collaboration" in global countermeasure (GCm), is connected. The IC-map can help students to organize their ideas and thoughts about climate change taking into account cause, influence, and countermeasure.

19.4 Discussions

In this research, we explored Korean high school students' understanding of climate change using an issue concept map (IC-map). The students' knowledge about climate change was various and complex. Using the IC-map worksheet, we also found that the students had misconceptions and misunderstandings of climate change.

They confused climate change with global warming, ozone layer depletion, and greenhouse gases. These confusions were also reported in precious research with university students and a preservice teacher (Ballantyne et al. 1998; Khalid 1999).

On the basis of these results, we suggest that science educators and curriculum developer should consider students' misunderstandings and misconceptions of climate change when they develop curriculum and teaching materials. Even though teachers and preservice teachers also have misconceptions about climate change (Boon 2010; Dove 1996; Groves and Pugh 1999), science teachers should foster a deep and clear understanding of the causes, influences, and countermeasures of climate change.

In this study, we used an IC-map to measure students' understanding of climate change. It is a complex scientific topic and also a socio-scientific issue (SSI). On the basis of the results of this study, we suggest that an IC-map can be a useful tool that can help teachers to understand their students' preconceptions and misconceptions about climate change and other SSIs. In addition, an IC-map is a good educational tool for students. It can provide scaffolding to express and extend students' thoughts and perceptions. Using an IC-map, students can expand their conceptions of scientific concepts such as climate change. We found that an IC-map allows students to consider the causes, influences, and countermeasures of climate change on a personal, societal, and global level. Korean students displayed two patterns of connection from their answers: "personal-societal-global" and "cause-influence-countermeasure." An IC-map can present students with a fundamental framework for exploring and integrating the concepts of climate change.

Acknowledgments This research was supported by the WCU (World Class University) program through the National Research Foundation of Korea funded by the Ministry of Education, Science and Technology (R32-20109). The authors thank the Research Group of the Global Institute for Science, Technology, and Society Education at Ewha Woman's University, South Korea. In particular, we wish to acknowledge the data collection and analysis efforts of Yunyoung Moon and Inae Chu.

References

Abbasi, D. R. (2006). *Americans and climate change: Close the gap between science and action*. New Haven: Yale School of Forestry and Environment Studies.

American Association for the Advancement of Science [AAAS]. (2007). *Atlas of science literacy*. Washington, DC: AAAS.

Anderson, B., & Wallin, A. (2000). Students' understanding of the greenhouse effect, societal consequences of reducing CO_2, emissions and why ozone layer depletion is a problem. *Journal of Research in Science Teaching, 37*(10), 1096–1111.

Aydin, F. (2010). Secondary school students' perceptions towards global warming: A phenomenographic analysis. *Scientific Research and Essays, 5*(12), 1566–1570.

Ballantyne, R., Witney, E., & Tulip, D. (1998). Developing students' environmental knowledge through interactive worksheets. *Environmental Education and Information, 17*(1), 1–16.

Boon, H. J. (2010). Climate change? Who knows? A comparison of secondary students and pre-service teachers. *Australian Journal of Teacher Education, 35*(1), 104–120.

Boyes, E., & Stanisstreet, M. (1993). The greenhouse effect: Children's perceptions of causes, consequences, and cures. *International Journal of Science Education, 15*, 531–552.

Boyes, E., & Stanisstreet, M. (1997). The environmental impact of cars: Children's ideas and reasoning. *Environmental Education Research, 3*(3), 269–282.

Boyes, E., & Stanisstreet, M. (2001). Plus ca change, plus c'est la meme chose? School students' ideas about the "greenhouse effect" a decade on. *Canadian Journal of Environmental Education, 6*, 77–101.

Brody, M., Chipman, E., & Marion, S. (1989). Student knowledge of scientific and natural resource concepts concerning acidic deposition. *Journal of Environmental Education, 20*(2), 32–42.

Center for Research on Environmental Decisions (CRED). (2009). The psychology of climate change communication. http://www.cred.columbia.edu/guide/

Choi, K., Lee, H., Shin, N., Kim, S., & Krajcik, J. (2012). Re-conceptualization of scientific literacy in South Korea for the 21st century. *Journal of Research in Science Teaching, 48*(6), 670–697.

Coyle, K. (2005). *Environmental literacy in America: What ten years of NEETF/Roper research and related studies says about environmental literacy in the U.S*. Washington, DC: National Environmental Education and Training Foundation.

Dijkstra, E. M., & Goedhart, M. J. (2012). Development and validation of the ACSI: Measuring students' science attitudes, pro-environmental behaviour, climate change attitudes and knowledge. *Environmental Education Research, 18*(6), 733–749. doi:10.1080/13504622.2012.662213.

Dove, J. (1996). Student teacher understanding of the greenhouse effect, ozone layer depletion and acid rain. *Environmental Education Research, 2*, 89–100.

Francis, C., Boyes, E., Qualter, A., & Stanisstreet, M. (1993). Ideas of elementary students about reducing the "Greenhouse effect". *Science Education, 77*(4), 375–392.

Gardner, G. T., & Stern, P. C. (2008). *The short list: The most effective actions U.S. households can take to curb climate change*. Philadelphia: Taylor and Francis Group. http://www.environmentmagazine.org/Archives/Back%20Issues/SeptemberOctober%202008/gardner-stern-full.html

Groves, F., & Pugh, A. (1999). Elementary pre-service teacher perception of the greenhouse effect. *Journal of Science Education and Technology, 8*, 75–81.

Hulme, M. (2009). *Why we disagree about climate change*. Cambridge: Cambridge University Press.

Intergovernmental Panel on Climate Change [IPCC]. (2007). *Climate change 2007 – Impacts, adaptation and vulnerability; contribution of working group II to the fourth assessment report of the intergovernmental panel on climate change*. Cambridge University Press.

Kerr, S. C., & Walz, K. A. (2007). "Holes" in student understanding: Addressing prevalent misconceptions regarding atmospheric environmental chemistry. *Journal of Chemical Education, 84*(10), 1693–1696.

Khalid, T. (1999). *The study of pre-service teachers' alternative conceptions regarding three ecological issues*. Paper presented at the annual meeting of the National Association for Research in Science Teaching, Boston.

Lee, H., Chang, H., Choi, K., Kim, S., & Zeidler, D. L. (2012). Developing character and values for global citizens: Analysis of pre-service science teachers' moral reasoning on socioscientific issues. *International Journal of Science Education, 34*(6), 925–953.

Leiserowitz, A. (2003). Global warming in the American mind: The roles of affect, imagery, and worldviews in risk perception, policy preferences, and behavior. Unpublished dissertation, University of Oregon, Eugene.

Leiserowitz, A. (2007). Communicating the risks of global warming: American risk perceptions, affective images, and interpretive communities. In S. Moser & L. Dilling (Eds.), *Creating a climate for change: Communicating climate change and facilitating social change*. Cambridge: Cambridge University Press.

Leiserowitz, A., & Smith, N. (2010). *Knowledge of climate change across global warming's six Americas*. New Haven: Yale Project on Climate Change Communication. http://www7.nationalacademies.org/bose/Climate_Change_Education_Leiserowitz_Workshop_paper.pdf

Ministry of Education, Science and Technology [MEST]. (2009). *National science curriculum*. Seoul: MEST.

Ministry of Environment [ME]. (2008). *The second report of Korean's awareness of climate change countermeasure*. Seoul: ME.

Mintz, J. (2006). "Global warming, what's that?" Student teacher understanding of the science related to sustainability issues. *Science Teacher Education, 46*, 2–3.

Morgan, M. D., & Moran, J. M. (1995). Understanding the greenhouse effect and the ozone shield: An index of scientific literacy among university students. *Bulletin of the American Meteorological Society, 76*(7), 1185–1190.

National Research Council [NRC]. (2007). Taking science to school: Learning and teaching science in grades K-8. In R. A. Duschl, H. A. Schweingruber, & A. W. Shouse (Eds.), *Committee on science learning, kindergarten through eighth grade*. Washington, DC: The National Academies Press.

Novak, J. D., & Gowin, D. B. (1984). *Learning how to learn*. Ithaca: Cornell University Press.

Papadimitriou, V. (2004). Prospective primary teachers' understanding of climate change, greenhouse effect, and ozone layer depletion. *Journal of Science Education and Technology, 13*(2), 299–307.

Parmesan, C. (2006). Ecological and evolutionary responses to recent climate change. *Annual Review of Ecology, Evolution, and Systematics, 37*, 637–669.

Patchen, M. (2006). *Public attitudes and behavior about climate change: What shapes them and how to influence them*. West Lafayette: Purdue Climate Change Research Center.

Pew Research Center for the People and the Press. (2007). *Global warming: A divide on causes and solutions, public views unchanged by unusual weather*. Washington, DC: Author.

Pew Research Center for the People and the Press. (2009). *Modest support for cap and trade policy: Fewer Americans see solid evidence of global warming*. http://people-press.org/files/legacy-pdf/556.pdf

Philander, G. (2008). *Encyclopedia of global warming and climate change* (Vol. 1). Thousand Oaks: Sage.

Pruneau, D., Khattabi, A., & Demers, M. (2010). Challenges and possibilities in climate change education. *US–China Education Review, 7*, 15–24.

Rye, J., Rubba, P., & Wiesenmayer, R. (1997). An investigation of middle school students' alternative conceptions of global warming. *International Journal of Science Education, 19*(5), 527–551.

Schreiner, C., Henriksen, E., & Kerkeby Hansen, P. J. (2005). Climate education: Empowering today's youth to meet tomorrow's challenges. *Studies in Science Education, 41*(1/2), 3–50.

Schuldt, J. P., Konrath, S. H., & Schwarz, H. (2011). 'Global warming' or 'climate change'? Whether the planet is warming depends on question wording. *Public Opinion Quarterly, 75*(1), 115–124.

Shepardson, D. P., Niyogi, D., Choi, S., & Charusombat, U. (2009). Seventh grade students' conceptions of global warming and climate change. *Environmental Education Research, 15*(5), 549–570.

Smith, C. L., Wiser, M., Anderson, C. W., & Krajcik, J. (2006). Implications of research on children's learning for standards and assessment: A proposed learning progression for matter and the atomic molecular. *Theory Measurement: Interdisciplinary Research and Perspectives, 14*(1/2), 1–98.

Stevens, S., Sutherland, L., & Krajcik, J. S. (2009). *The big ideas of nanoscale science and engineering*. Arlington: National Science Teachers Association Press.

Storksdieck, M. (2006). *Field trips in environmental education*. Berlin: Berliner Wissenschafts-Verlag.