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Status of Integrated Science Instruction in Junior Secondary Schools of China: An Exploratory Study

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Abstract: Integrated science curriculum has been implemented in the junior secondary level in China for two decades. However, the implementation of the integrated science curriculum is behind expectation in most provinces. Various challenges encountered by science teachers in their instruction of integrated science were reported but without fine-grained investigation. Here, we present a study on exploring the instruction of integrated science in secondary level for exposing major problems in details in the science classroom. In this study, a series of classroom observation instruments were used for collecting and analyzing data on teachers' performance on lesson enactment. Teacher verbal behavior, instructional organization, instructional content, and student verbal behavior and learning activities were adopted and examined. Findings revealed that students were provided with limited opportunities for participating and engaging in learning as science teachers were dominant in classroom talk. The teachers highlighted the integration of knowledge within one subject (within-subject knowledge), but undermined the integration of knowledge between subjects (cross-subject knowledge), which led to the unsuccessful instruction of the integrative content. And their inadequate competencies in designing and teaching STS content, scientific inquiry, and scientific experiments also affected the quality of integrated science instruction.

Keywords: Integrated Science Curriculum, Classroom Observation, Science Teachers

Introduction

The implementation of integrated science, an interdisciplinary subject that intentionally applies methodology and language from more than one science disciplines (e.g. biology, chemistry, physics, earth science, life science) to address a scientific theme, topic, or problem (Jacobs, 1989), has been frequently discussed in literature (Adeniyi,1987; Andersson, et al., 2010; Arcà & Missoni,1981). Integrated science education emphasizes fundamental unity of scientific knowledge and encourages students to combine perspectives, concepts and methods from various disciplines to comprehend and interpret scientific phenomena in daily life (Frey, 1989). Research has shown that this instructional approach can improve students' understanding of those complex scientific phenomena and the role and function of science in contemporary society (Blum, 1973; Fogarty, 1991; Wei, 2009).

Although there are a number of successful "stories" reported and shared in literature (Crane, 1991; Nordine, Krajcik, & Fortus, 2011; Riquarts & Hansen, 1998), science educators still face challenges when implementing the integrated science curriculum at the secondary level. In Australia, the persistence of traditional patterns of assessment, parental pressure for traditional academic standards, subject-based qualification, restricted instructional periods, insufficient teaching materials, unqualified teachers, and the lack of school collaboration were found negatively impacting the implementation of integrated science (Venville, Wallace, Rennie, & Malone, 2002). Teacher shortage was identified as an important factor that obstructed the implementation of integrated science curriculum in America (Harrell, 2010). Apart from this, that teachers lacked in content knowledge of integrated science was noted as another problem. Thus, different countries confronted different issues on the implementation of integrated science, and the teacher factor especially for pertaining to teacher attribute related to the instruction of integrated science (e.g. belief, content knowledge, teaching skills, pedagogical content knowledge) has been a common issue identified (Diaconu, Radigan, Suskavcevic, & Nichol, 2012).

In China, the teacher factor has been defined as the most prominent factor and it has also been one of most frequently discussed topics in relevant studies on integrated science. Among these studies, most investigated teacher factor using common methods (e.g. interview, survey and questionnaire) and drew conclusions without rigorous classroom observation. The situation leads to the generation of multiple superficial studies and probably the provision of the subjective and one-sided views on the problems of integrated science instruction. Consequently, to fill the research deficiency and to obtain more specific and objective vision of the challenges and problems encountered by science teachers in the instruction of integrated science, we conducted the study focusing on analyzing and comparing teachers' performance in the classrooms of Chinese secondary schools through in-depth classroom observation. Based on findings and discussions, the problems in the instruction of integrated science were detected and exposed. Conclusions and implications on research and instruction were provided at the concluding part for directing the implementation of integrated science instruction.

Integrated science curriculum in China

Acknowledging the benefits, science educational researchers and practitioners in China have pursued integrated science instruction in lower secondary schools for long time. This is reflected in the development of the science curriculum. As early as 1913, integrated science had been already an important component of the science curriculum which consisted of two subjects[1]—*Natural Science* (*Bowu* in Chinese) and *Physics-Chemistry*. The former combined domain knowledge from botany, zoology, physiology and mineralogy and the latter integrated domain knowledge from physics and chemistry (Liu, 2001). During 1920s and 1930s when Progressivism exerted a profound influence on the educational system in China (Chen, Wang, & Shen, 2012), integrated science textbooks were designed and used in parallel with the ones for compartmentalized science (i.e. teaching science as an isolated and separate discipline, such as biology, chemistry, and physics) in secondary schools. However, due to the influence from the Soviet Union's education system in the following years, compartmentalized science curriculum became the dominant in secondary science education. From 1950s to 1970s, physics, chemistry, geography, botany and zoology were all taught in absolute isolation (Yang, 2009). From this brief review, we could recognize that compartmentalized science instruction played a major role in secondary science education though there were some instances of practicing integrated science from early time in China.

The situation was not changed until the 1980s. In correspondence with the international curriculum reform and the STS (the Science, Technology, and Society) initiative in the 1980s (Jong, 2007), integrated science instruction resumed its position in the science curriculum. Moreover, in the year of 1988, Chinese State Education Commission (SEdC) appointed the secondary school affiliated to Northeast Normal University (the junior section) in Changchun city and junior secondary schools in Shanghai city and Zhejiang province as the pilot schools for integrated science

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[1] In this paper, integrated science refers to the science curriculum which is taught in junior secondary schools. The original name of the integrated science was Natural Science in China, which merged the domain knowledge from the scope of biology, physics, chemistry and geography. In 2001 curriculum reform, the name of Natural Science was changed to Science (Author, 2010).

education. This pilot project has been regarded as one of the most significant science education reforms in China. The piloting implementation proved effective and successful within the trial years (Wang, 2007; Yu, 2002). Following a large scale new curriculum reform in China in 2001, a group of elite science curriculum experts, researchers, and teachers were convened and assigned to develop the first version of integrated science curriculum standards for junior secondary schools—*the Science Curriculum Standards of Compulsory Education in Full-Time Schooling System (experimental version)* by Chinese Ministry of Education (MOE) (MOE, 2001). The curriculum standards were intended to guide teachers' design and enactment of integrated science lessons in junior secondary schools. Besides, in accordance with the policy of "One Syllabus and Multiple Textbooks"[2], four sets of integrated science textbooks were developed and adopted successively in schools where the traditional compartmentalized science curriculum gave way to the integrated one. On the other hand, an increasing number of universities (from one in 2001 to 64 in 2007) set up an undergraduate major of "Science Education" (Deng, 2011).This was in response to the emerging issue that most science teachers lacked in both awareness and abilities of teaching subject knowledge outside their own specialized discipline due to the pre-service training they received that only focused on compartmentalized science education before 2000 (Zhang & He, 2012). Hence, to sustain the implementation of integrated science curriculum, great efforts have been devoted to supporting the

[2] The textbooks used at the beginning of New China were mostly translations of textbooks from other countries (e.g. Soviet Union). The curriculum had a lot of foreign input. Then a department of People's Education Press (PEP) took the charge of developing and publishing textbooks for primary schools and secondary schools. During this period "One Syllabus and One Textbook" was dominant. From 1987, following a series of policies the national government published, the researchers and teachers in Beijing, Shanghai, Zhejiang and Guangdong, started to develop textbooks by themselves. Different versions of textbooks were thus developed and used in different provinces. It was defined as the period of "One Syllabus and Multiple Textbooks" in China (Zhong, 2009).

instruction of integrated science through developing curriculum standards and curriculum materials, and improving teacher education programme.

Despite the continuous efforts made by multiple stakeholders to sustain and scale up integrated science[3], most pilot schools in the experimental areas such as Hunan, Hubei and Shanghai had given up the integrated science program and returned to the compartmentalized science instruction, because of various reasons, such as teachers qualifications, textbooks, assessment and parental pressure (Hu, 2008b). A typical example was that the junior secondary schools in Wuhan (a city in Hubei province) all returned to the compartmentalized science in 2009 after implementing the integrated science curriculum for about five years (Yuan & Cai, 2004). In this case, teachers' qualification and their ability of the adaption to the instruction of integrated science had been one of the dominant reasons for the failure of this pilot implementation of integrated science in Wuhan (Chen & Luo, 2009).

Despite successful cases exist in China, such as Zhejiang and Shenzhen, where local governments provide full support for the implementation of integrated science in schools, and professional teams including curriculum educators, scientists, science educators, researchers and teachers endeavor to develop teaching materials and organizing training sessions for teachers to adapt to the integrated science instruction (Harrell, 2010), the difficulty in implementing the integrated science has been widely reported in existing literatures in China. The reasons underlying the predicament of integrated science instruction in junior secondary schools are more complicated than our expectation and are still under exploration. By reviewing the previous studies, we

[3] According to the report of the investigation of science education in China in 2003, integrated science had been covered in all of the junior secondary schools in 13 out of 34 provinces since the start of the 2001 curriculum reform. 526,000 students participated in this curriculum (Pan, 2005).

refine the main issues and challenges teachers' encountered in their implementation of integrated science. Meanwhile, the literature review helps to expose limitations in existing research, as well as to form the research questions for the study.

Previous Studies

To grasp the overall status of the implementation of integrated science curriculum in China, we extensively reviewed relevant degree theses and top-ranked Chinese educational journal papers from 2000-2010, and finally adopted representative literatures on the study of the integrated science implementation.

The selected literatures studied the implementation of integrated science and revealed the problems identified in the instruction of integrated science, as well as provided suggestions to inform the teaching and research of integrated science curriculum. Among these literatures, two categories of studies were identified. One category referred to the studies on comprehensive factors impacting the curriculum implementation (e.g. policy, curriculum, community), the other analyzed factors related to the teacher attribute (e.g. qualification, belief, PCK). Among them, most studies detected the factors which negatively influenced the implementation of integrated science. Fan's (2006) study drew valuable conclusions on the negative factors during the curriculum implementation through interviewing different parties. He concluded that school principals, administrators, teachers and researchers shouldered the main responsibility for the problems on the implementation of integrated science. The principals were found lacking in sophisticated understanding of integrated science and the administrators failed to provide enough support for its implementation. The findings of empirical studies didn't succeed in informing teachers' instruction. Luo's (2006) study found that teachers' subject specialism[4], work load, and content knowledge, as well as the inappropriate assessment methods and insufficient teaching resources influenced the quality of integrated science instruction.

By reviewing studies focusing on teacher factor, the frequent discussion was teachers' competency and the teacher education of integrated science instruction. Using the similar methods (e.g. questionnaire), Hao, Jiang and Zhang (2006) uncovered that science teachers still taught integrated science knowledge in separate ways. They had inadequate teaching skills for integrating knowledge from different disciplines. Moreover, besides the limited teaching skills of integrated content, Lu's (2007) study exposed that teachers' inquiry skills, content knowledge, content structure, and beliefs also influenced the instruction of integrated science. Further, after collecting teachers' feedback on their professional training, Li and Zhang (2003) demonstrated that the lack of systematic professional training was another problem for the compromised integrated science instruction. Similar findings were also noticed in other studies (Hu, 2008a; Wang, Ma, & Fan, 2007).

Among all the factors that negatively impacted the implementation of integrated science in China as identified above, a key factor was related to the science teacher, the main agent in the classroom (Schneider, Krajcik, & Blumenfeld, 2005). It was found that science teachers had insufficient knowledge of subject content, content

[4] In China, because the lower status of the integrated science existed for long time, there were few of universities established the major of science education for educating and training pre-service teachers for integrated science before 2001. Therefore, most of current integrated science teachers specialize in narrow areas within the domain of science, such as biology, chemistry, physics, biology, biochemistry, etc. Thus, in this paper, teachers' subject specialism refers to their major or academic background in universities before they become a formal integrated science teacher in secondary schools.

structure, pedagogy, and possessed inadequate competence in teaching integrated content and scientific inquiry hindered the enactment of integrated science instruction. Moreover, influenced by their subject specialism, science teachers usually focused too much on instructing subject-specific knowledge, and they intended to teach integrated science in the separate way. These also negatively impacted the quality of integrated science instruction, and the optimization of the value of integrated science. These all pointed out the necessity to envision systematic professional training for teachers to encourage extensive and effective adoption of integrated science in lower secondary schools as discussed in Li and Zhang's (2003) paper.

The limitations on the above studies were identified meanwhile. First, although science teachers' subject specialisms had be found related to the quality of their instruction, the investigation of the commonalities and differences in the way science teachers with diversified subject specialisms enacted integrated science instruction was, to some extent, neglected in previous research, and little attention was paid on the examination of the relations of their subject specialisms and the performance on instruction. Second, evidence from the in-depth classroom observation was rarely reported in these studies. The results were mostly obtained by interview or surveys instead of through capturing teachers' action in classroom (e.g. class management, verbal behavior, interactions with students, the organization of instructional content) (Flanders, 1970; Mortimer & Scott, 2003; Simmons, et al., 1999). Finally, as previous studies mainly focused more on the results than the process, the teaching and learning processes unfolding in integrated science lessons had not been subjected to rigorous empirical investigation. For example, the ways the teachers manage class activities, present instructional content and interact with their students were rarely analyzed and discussed. Aiming to bridge the research gaps identified, this study looks into the main problems or issues teachers encountered in the process of instructing integrated science in classroom through systematic classroom observation.

Purposes and Research Questions

An empirical study was conducted to probe teaching and learning processes in integrated science classroom at the lower secondary level in this paper. To get deep insights into teachers' performance in the class, especially for their ways to manage students' activities, present instructional content, as well as interact with students, three dimensions with their sub-dimensions were chosen as the indicators to observe teachers' performance. A series of observation instruments based on these sub-dimensions were developed and used for data collection. Data analysis was performed to investigate whether there were discrepancies in the way teachers with different subject specialisms instructed integrated science, in which aspects they had more difficulty in teaching integrated science. In the last section, how the findings could inform future implementation of integrated science in lower secondary schools was discussed. The following research questions were explored via data analysis:

1. What were the main challenges faced by teachers when teaching the integrated science curriculum?
2. Were there any differences in the instruction of integrated science among teachers with different subject specialism?
3. If yes, what were the major differences in the instruction of integrated science among teachers with different subject specialism?

Methods

Participants

A total of 36 science teachers (18 males and 18 females) from six junior secondary schools in eastern Zhejiang province participated in this study. The specific selection criteria were:

a. To minimize difference in teaching competences, all participants were selected from ordinary junior secondary schools, not from key junior secondary schools[5].

b. They had a wide array of subject specialisms in the domain of science subject. Among all the participants, the number of teachers specialized in physics, chemistry, and biology was respective nine; the number of teachers specialized in biochemistry, geography and science was respective three.

c. They had strong willingness to participate in the study; and they were interested in our study and had willingness to share and discuss their lessons with researchers.

Additionally, the classes (Grade 7 and Grade 8) chosen performed equivalently in their regular science tests. On average, there were around 40 students in each class with equal distribution of girls and boys.

Procedures

Before class, the teachers were required to complete a questionnaire in which their educational background, subject specialism, teaching experience, and professional positions were stated. This was used to obtain valuable evidence for conducting

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[5] In most parts of china, secondary schools are generally rated as ordinary schools and key schools. In the key schools, most teachers have more sophisticated teaching skills and richer working experience compared to those who teach students in the ordinary schools. The students admitted to the key schools should achieve higher scores of entrance examination than those accepted by ordinary schools. The number of the ordinary secondary schools is much more than the key secondary schools in the same area. So the participants from ordinary secondary school can better represent most of teachers in the same area.

comparisons amongst teachers. We also conducted short interviews (approximately 15 minutes for each teacher) with these teachers to gather information about their classes (e.g. the number of students, the ration between male students and female students, students' science competency) to further confirm the equivalence of class ability.

Classroom observation was conducted by four researchers including first author in the school year of 2009. 36 classes from six junior secondary schools were involved. Each teacher was in charge of one class. The classroom observation followed school terms and lasted approximately three months. We observed each teacher one lesson in his/her class considered the limited time and manpower. It was hoped that the teacher could behave naturally in the lesson observed. Thus, teachers were required to follow the general lesson plans as they did in their normal lessons. Multiple data sources including observation instruments, field notes, onsite videos and audios were used for data collection in classroom observation. Field notes were employed to record the lesson sequences and activities in class. The video and audio equipments were set up for capturing teacher and students' performance in the class. The videos and audios would be transcript for data analysis. During classroom observation, we participated with minimum intervention in order not to affect teachers' instruction and students' activities during each session.

The lesson modules and topics adopted were aligned with the content of science textbook used in Zhejiang province (Zhu, 2005). The general information of lesson arrangement is presented in Table 1.

Table 1. General information of the arrangement of the lessons

Module	Topic	Grade	No. of classes	Teachers' specialism	No. of teachers
Life Science	Neuroregulation	8	3	Chemistry	3
			3	Biology	3
			3	Physics	3
Materials Science	Circuit	8	3	Physics	3
			3	Science	3
			3	Biochemistry	3

	Substance and Models of Particle	8	3 3	Chemistry Biology	3 3
Earth, Cosmos and Space	Sun and Moon	7	3 3 3 3	Geography Biology Chemistry Physics	3 3 3 3

24 science teachers with different subject specialisms taught the topics of Neuroregulation, Circuit, Substance and Models of Particle in 24 Grade 8 classes, and another 12 science teachers taught the topic of Sun and Moon in 12 Grade 7 classes. This design facilitates us to:

a. Analyze the general performance of science teacher in class;

b.Compare the performances of teachers with different specialisms when teaching the same topics;

c. Compare the performances of teachers when teaching the knowledge within and outside their specialisms.

Instruments Development and Data Analysis

To develop the observation instruments for classroom observation on teacher performance, relevant principles on studying teachers' instruction were adopted. Considering the complexity of classroom system (Cassady, et al., 2004), we proposed to establish the dimensions for classroom observation based on the principle of LICC (Learning, Instruction, Curriculum, and Culture) which studied class in a systematic way. LICC approach was developed by a group of Chinese scholars through two-year empirical studies. It had been demonstrated as a validated and effective tool for assessing teachers' performance on instruction from a systems perspective (Cui, 2010). LICC advocated that classroom observation should focus on four dimensions: Learning (whose sub-dimensions include preparation, listening, interaction, individual work, and achievement), Instruction (whose sub-dimensions include phase, presentation, verbal behavior, guide, talent), Curriculum (whose sub-dimensions include objective, content, implementation, assessment, resource) and Culture (whose sub-dimension include thinking, democracy, creation, love, character) (Cui, 2010; Shen & Cui, 2008). And specific observation instruments were designed and implemented for observing each dimension in LICC classroom observation mode. As the present study focused on examining the learning and teaching processes mainly reflected by instructional content and teacher and student behavior, the adoption of LICC classroom observation dimensions was appropriate and feasible for us to conduct classroom observation in more systematic way. According to the purpose of the study, the dimensions of instruction, curriculum and learning were chosen as the core components for observation, and the dimension of culture was excluded. Besides, indicators including instructional organization, teacher verbal behavior, instruction content, students' activities and their verbal behavior for these dimensions would be further identified and defined in accordance with LICC principles and relevant literature (See following sections).

Analyzing instruction in integrated science lessons

In analyzing instruction, we focused on teacher verbal behavior from LICC sub-dimensions and their instructional organization, the two legitimates and commonly used indicators for evaluating teachers' skills on knowledge presentation and class management (Beomme & Steinbring, 1994; Chin, 2007). To investigate teacher verbal behavior, Flanders Interaction Analysis Categories (FIAC), distinguished 5 types of teacher in-class language, namely, asking questions, accepting ideas, lectures, memorizing, and giving directions, was adopted (Borich, 1994; Flanders, 1970). To reduce the volume of data, the coding interval was revised from 3 seconds to 15 seconds and represented by a block in the observation form (Table 2). A typical class observed was 40 minutes comprising 160 blocks. The distribution of different types of teacher verbal behavior occurred in one class was reflected by the frequency of each category appeared.

Table 2. The coding scheme for teacher verbal behavior

Types of language	1	2	3	4	5	……	160
Ask questions							
Accept ideas							
Lectures							
Memorize							
Give directions							

The indicators for examining instructional organization adopted included instructional purpose, managing time, managing students' activities, responding to students' answers and summarizing learning points (NCES, 2006). These five indicators were examined to evaluate teachers' class management and teaching strategies (Martin & Sass, 2010). A five-point Likert scale (1= poor, 2 = fair, 3 = good, 4 = very good and 5 = excellent) was used in coding. For instance, if the teacher stated the learning objectives clearly at the beginning stage of the lesson, and emphasized the purpose of each activity, he or she would receive a high score on the item of purpose statement.

Analyzing learning in integrated science lessons

With respect to learning, we primarily examined the type of learning activities as LICC proposed in its sub-dimensions and verbal behavior of students in the integrated science class. Three types of learning activities, namely, student individual activity, student collaborative activity and student-teacher collaborative activity were identified. The examination of the frequency of different activities could unveil teachers' skills in conducting and managing students' activities, as well as their patterns of interacting with students. In categorizing student verbal behavior, FIAC approach was again adopted. Using the same coding interval (15 seconds), student verbal behavior was exclusively coded into four categories including answers, descriptions, comments and questions (Flanders, 1970; Ogunniyi, 1984). The investigation of students' in-class talk helped to identify their involvement in class and their interaction with the teacher (Bruce, 2007)**.**

Analyzing curriculum in integrated science instruction

As discussed in previous studies, the teaching of instructional content was related to teacher's knowledge on the content and their skills on integrating content from different disciplines in the integrated science (Hao, Jiang, & Zhang, 2006; Lu, 2007; Luo, 2006). Regarding curriculum, our analysis focused on the organization of instructional content in the integrated science lessons, which, to a great extent, reflected the knowledge base, design skills, teaching skills and strategies of a teacher (Käpylä, Heikkinen, & Asunta, 2009). Guided by the LICC sub-dimensions in the curriculum (e.g. content, implementation) and the learning content of Chinese national science curriculum standards, the instruction of five types of contents including within-subject knowledge, cross-subject knowledge, scientific inquiry, experiments and STS content integrated into integrated science lessons was examined and assessed in class (MOE, 2001). These items were defined as the core components of the integrated science curriculum in the current science curriculum in China (Cai, 2007). Multiple forms of representations had been used to represent these contents in the science textbooks.

In the integrated science curriculum, within-subject knowledge referred to the concepts, methods, or principles from one discipline; the instruction of within-subject concepts was regarded as the integration of knowledge within one discipline (Fogarty, 1991). The cross-subject knowledge was usually related to the introduction of the within-subject knowledge, i.e. knowledge pertaining to the concepts, methods or principles involved in or relative to the instruction of the within-subject knowledge but from another subject domain (Killen, 2005). The instruction of cross-subject concepts could be defined as the integration of knowledge between subjects. For instance, photosynthesis was a key topic introduced in the lesson when students study the theme of “Plants Reproduction and Growth”, the concepts: leaf structure, chloroplast, chlorophyll, and tree root could be identified as the within-subject knowledge as they were the major target concepts and belonged to the domain of biology. The chemical equation employed to explain the mechanism of photosynthesis could be viewed as the cross-subject knowledge which was from the domain of chemistry.

Scientific inquiry referred to the activities that aimed to improve students’ conceptual understanding, develop scientific process and inquiry skills (e.g. identifying variables, formulating hypothesis, collecting data, analyzing data) as well as relevant learning skills through engaging them into structured, guided inquiry or open inquiry mode (NIH, 2001; Zion, Cohen & Amir, 2007). Experiments included both laboratory and outdoor experimental activities in which students followed prescribed procedures in order to observe real scientific phenomena or tested a theory to develop understanding in science concepts, scientific methods and experimental skills through participating in a series of hand-on work. STS content was the content knowledge taught within the relations of “technology” and “society”. This content was designed to improve students’ understanding of social issues both external and internal to science and the interactions among science, technology, and society (Aikenhead, 2005).

This study, apart from examining the time distribution of each type of instructional content, also investigated the scope and depth of each content incorporated. This would be achieved by analyzing the frequency of specific types of knowledge or skills being instructed and the time allocated to them. More details on the analytical methods are depicted in the subsections below.

Analyzing subject knowledge

When analyzing the subject knowledge, we coded each instance of (a) within-subject knowledge or (b) cross-subject knowledge using two parameters based on the Revised Bloom's Taxonomy (RBT) (Anderson & Krathwohl, 2001; Bloom, 1956).

a. Knowledge Type: A-Factual knowledge, B-Conceptual knowledge, C-Procedural knowledge, and D-Metacognitive knowledge.

b. Cognitive Level: 1-Remember, 2-Understand, 3-Apply, 4-Analyze, 5-Evaluate and 6-Create.

This taxonomy provided a means to evaluate both the scope and depth of learning which extended way beyond the simple acquisition of knowledge. Table 3 illustrates the coding form for subject knowledge based on RBT (Krathwohl, 2002). The total number of concepts, their knowledge types and cognitive levels, and the time allocated to teach these concepts would be calculated for assessing the integration of subject knowledge.

Table 3. The coding scheme for subject knowledge

Knowledge Type	Cognitive Level \ Knowledge Domain											
	1 remember		2 understand		3 apply		4 analyze		5 evaluate		6 create	
A. Factual	A_{1a}	A_{1b}	A_{2a}	A_{2b}	A_{3a}	A_{3b}	A_{4a}	A_{4b}	A_{5a}	A_{5b}	A_{6a}	A_{6b}
B. Conceptual	B_{1a}	B_{1b}	B_{2a}	B_{2b}	B_{3a}	B_{3b}	B_{4a}	B_{4b}	B_{5a}	B_{5b}	B_{6a}	B_{6b}
C. Procedural	C_{1a}	C_{1b}	C_{2a}	C_{2b}	C_{3a}	C_{3b}	C_{4a}	C_{4b}	C_{5a}	C_{5b}	C_{6a}	C_{6b}
D. Metacognitive	D_{1a}	D_{1b}	D_{2a}	D_{2b}	D_{3a}	D_{3b}	D_{4a}	D_{4b}	D_{5a}	D_{5b}	D_{6a}	D_{6b}

** e.g. A_{1a}: to remember the within-subject factual knowledge. A_{1b}: to remember the cross-subject factual knowledge.*

Analyzing scientific inquiry

In the analysis of scientific inquiry, we employed the categorical framework proposed by Wenning (Wenning, 2005), an extension on the original theory of scientific inquiry levels first developed by Schwab, Brandwein and Herron (Herron, 1971; Schwab & Brandwein, 1962). In this framework, four levels of scientific inquiry skills: 1-Rudimentary Skills, 2-Basic Skills, 3-Integrated Skills and 4-Advanced Skills were differentiated. These skills could be further described with reference to the agents, the one (s) who were supposed to carry out the inquiry activities (A-Teacher, B-Teacher & Student, C-Student Group, or D-Individual Student). See table 4. With the changes of the agent from A to D, the inquiry level increased from the lowest to the highest level; The inquiry level also accordingly increased when the inquiry skills involved move from rudimentary skills to the advanced skills. For instance, if students engaged in an individual inquiry activity which only required applying observation, discussion and measurement skills, the level of the scientific inquiry was coded as D_3. In the study, the number and level of inquiry activities enacted and the time allocated would be calculated to inform teachers' integration of science inquiry in the lessons.

Table 4. The coding scheme of the scientific inquiry

Inquiry Level	Agent		1.Rudimentary skills	2.Basic skills	3.Integrated skills	4.Advanced skills
Low	A	Teacher	A_1	A_2	A_3	A_4
↓	B	Teacher &students	B_1	B_2	B_3	B_4
	C	Students group	C_1	C_2	C_3	C_4
High	D	Individual Student	D_1	D_2	D_3	D_4

Analyzing experiments

In evaluating the design and implementation of experiments, two indicators, namely, agents, the one (s) who were supposed to conduct the experiment (A-Teacher, B-Teacher & Student, C-Student Group, or D-Individual Student), and the number of scientific methods (1, 2 or more than 2) involved (Hodson,1992), were adopted

(Develaki, 2010; Hofstein & Lunetta, 2004) (Table 5). The design level increased with the increment of methods involved in the experiment. For instance, if the students were required to apply more than two scientific methods in conducting an experiment collaboratively, the experiment was coded as C_3. In the study, the integration of experiments would be examined by analyzing their design levels, frequency and the time distribution.

Table 5. The coding scheme for experiments

No. of scientific methods	Teacher	Teacher-Student	Student Group	Individual Student
1	A_1	B_1	C_1	D_1
2	A_2	B_2	C_2	D_2
> 2	A_3	B_3	C_3	D_3

Analyzing STS content

With regard to STS content, the integrating approach and knowledge domain were adopted as the main indicators for assessment (Aikenhead, 1992). The former referred to the way the STS content integrated into the lesson—whether it was used in the form of A-Reading materials, B-Quiz, C- Problematized context, or integrated into D-Inquiry activities in instruction. The latter referred to the domain of knowledge (e.g. 1-within subject knowledge and 2-cross subject knowledge) to be acquired through incorporating STS content. See the coding scheme in Table 6. We examined the integration of STS content through calculating the number of STS content, identifying its integrating approach and knowledge domain, as well as the time distribution.

Table 6. The coding scheme for STS content

Types	Reading materials	Quiz	Question context	Inquiry
Within-subject knowledge	A_1	B_1	C_1	D_1
Cross-subject knowledge	A_2	B_2	C_2	D_2

** e.g. A1: STS content used as reading materials in the instruction of within-subject knowledge*

In data analysis, two researchers (including the first author) replayed, transcribed and coded classroom videos and audios using the proposed coding instruments. Inter-rater agreement of the coding (Cohen's Kappa) was calculated. The k value reached 0.86, indicating good agreement between the two raters.

Findings and Discussion

Teachers' instructional organization

A descriptive statistical analysis was conducted to show teachers' performance in terms of instructional organization in their classes. Overall, teachers' general performance on instructional organization attained the level of "Good" (all mean scores reached more than 3 points), especially for the management of students' activities (the mean score was 3.75) (Table 7). This indicated that most science teachers could manage students' activities well and provide appropriate feedback for students' answers, and they could also explain the purposes of the activities and summarize the content at the end of lessons. Thus, initial conclusions could be drawn that science teachers had general competencies in teaching and managing integrated science class.

Further analysis revealed that teachers' performance was varied on some aspects of instructional organization. For example, there were teachers (30%) who performed quite well and nearly gained full score on the items of time distribution, purpose statement, activity management and summary, yet there were also the ones whose performance was rather unsatisfactory and hence received the lowest score (32%). The differences of teaching performance were most evident in managing students' activities (M=3.75; SD=1.497) and stating the teaching purposes (M=3.58; SD=1.443). This could be attributed to the differences in teachers' subject specialisms and teaching experiences, both which demonstrated by the further data analysis below (Hacker & Rowe, 1985).

Table 7. Descriptive analysis for teachers' instructional organization

Items	Minimum	Maximum	Mean	SD
Time distribution	1	5	3.33	1.231
Purpose statement	1	5	3.58	1.443
Response to answers	2	4	3.50	0.674
Management of students' activities	3	5	3.75	0.754
Summary	1	5	3.67	1.497
Total	8	24	17.83	5.559

Moreover, we noticed that most teachers received the lowest score on time distribution (about 50% of teachers gained 3 or even lower score), indicating that the teachers tended to perform comparatively poorly in time management. The problem of time distribution was further detected based on the analysis of the time allocation of different types of instructional content. Figure 1 shows the time distribution on instructional content of "Sun and Moon" by teachers with different subject specialisms. As indicated in Figure 1, teachers, regardless of their different subject specialisms, might tend to regard the teaching of subject knowledge within one discipline as the priority and spent a considerable more class time on instructing concepts from one subject, which in turn, compromised the instruction of other contents (cross-subject knowledge and experiments in particular). This could be explained by teachers' deficits in the teaching of content knowledge concerning other subjects or incapability to incorporate these contents into their teaching. Another explanation might be that teachers lack awareness to integrate these instructional contents.

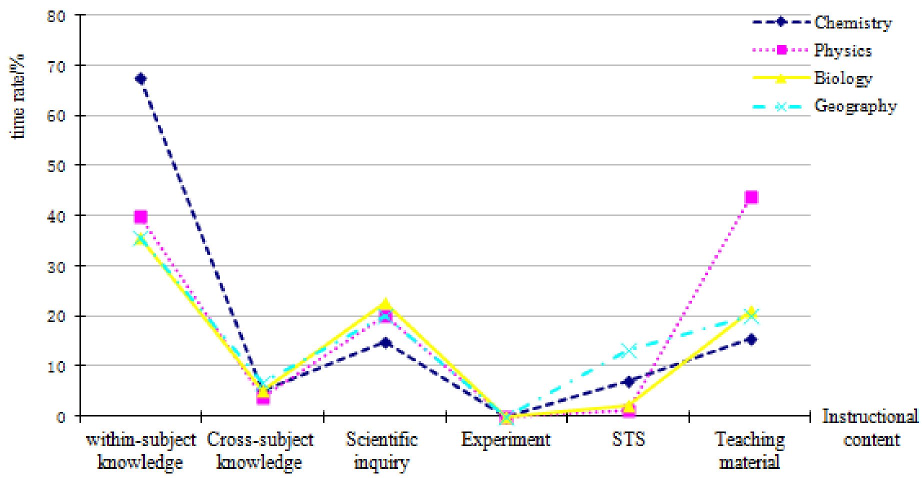

Figure 1. Time distribution on different instructional content

In addition, teacher specialism effect was most evident on the instruction of different types of instructional content. And teachers also performed differently in the way of using teaching materials, such as textbooks, PPT slides, videos and audios (Forbes, 2011).

Besides imbalanced time distribution, some of the teachers were also found to be lacking in expertise in handling students' answers. When an answer was proposed by the student, the teachers would tend to validate answers for students without exploring more about students' ideas. Such teachers' responses were not likely to promote an environment where students could share, discuss and debate the reasonableness and validity of their ideas (Crespo, 2002). This reflected teachers' lack of teaching skills and strategies that were generally required for every teacher in questioning skills (not specifically demanded for integrated science teachers).

Based on above analysis, teachers' general performance in the instruction of integrated science was measured. The results suggested that science teachers had basic competencies in conducting the lessons, but varied in some aspects. Their time distribution on the instructional content was not equivalent and was affected by their specialisms, and their responses to students' answers reflected their inadequate skills in capturing students' ideas or knowledge via questions or challenging their current ideas.

Teacher verbal behavior

Teachers' average time distributed on asking questions, accepting ideas, lectures, memorizing, giving directions in class is presented in the line graph below. As Figure 2 shows, on average, 41.88% of the class time was occupied by teacher talk (the item is annotated as "languages" in the graph). According to Flanders' "Two-Thirds Rule" of teacher-student classroom interaction, if about two-thirds of the classroom time was devoted to talking, about two-thirds of the talking was done by the teacher and two-thirds of the teachers' talk was "direct" talk, we could say this class was teacher-dominated (Inamullah, Nasser, & Hussain, 2008). Following this "Two-Thirds Rule", the integrated science lessons we observed could be defined as the "teacher-dominated" in which student agency was undermined. This form of instruction usually left students few opportunities to participate and engage in their learning process (Wallacne & Louden, 2002).

Specifically, most teachers devoted most efforts to lecturing (24.49%), and less time was spent in asking questions (9.77%), giving directions (6.48%), and responding to students to accept ideas (0.49%). Looking into their performance on responding to students, we found that teachers were hesitant to encourage students to generate ideas through reiterating the questions or provided scaffolds (e.g. prompts, scripts, challenging their ideas) (Chin, 2007), which lead to the low ability students seldom succeeded in identifying questions or seeking solutions guided by teachers. These students were reduced to passive recipients of information and followers of directions, which, in turn, discouraged their participation and engagement in the learning activities.

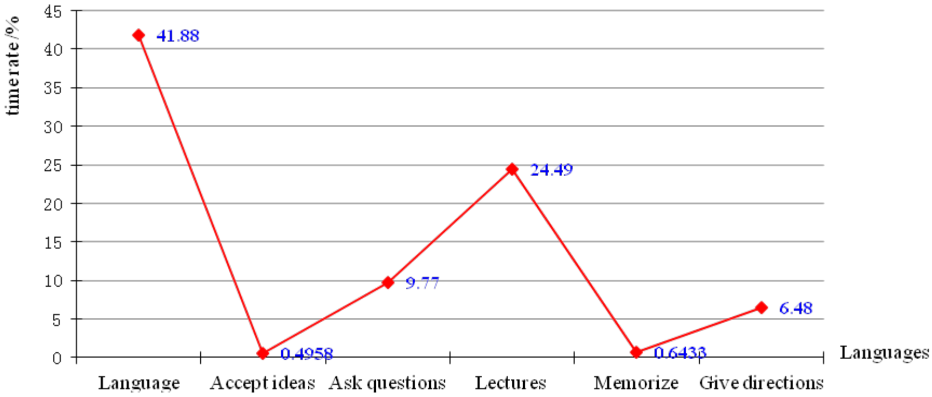

Figure 2. Time distribution of the teacher utterances

In summary, teacher-guided classes were dominated in which students were received few opportunities to discuss, share and elaborate their ideas via debating with their partners or being guided by the teacher, because most teacher efforts were devoted to lectures compared to guiding and interacting with students. Further, the findings of time distribution on each category of verbal behavior demonstrated again that science teachers had problems in distributing instructional time in class, which reflected their limited skills on delivering good integrated science lessons.

Student verbal behavior and learning activities

The descriptive analysis results about student verbal behavior and learning activities are presented in Table 8. As mentioned above, teacher talk was dominant in the class, as a result, student "voice" was only heard in around one fifth of the class time (20.9%). Analyzing the frequency and the content of their verbal behavior, we found that students received more opportunities to answer the questions (40%) but fewer chances for expressing their ideas (25%), as well as least time to raise questions (10%) and post comments (15%) to specific content. This indicated that the teachers provided limited opportunities for students to construct knowledge through active and effective interaction, especially when the students were in the collaborative activities (Feldman, 1996).

Table 8. Students' verbal behaviors and activities

Items	Minimum	Maximum	Mean	SD
Languages (Student talk)	11.25	33.50	20.9075	7.13350
Activities	7.78	43.75	27.7783	10.54463
Individual work	.00	15.00	4.3983	4.37890
Collaborative work	3.33	37.50	18.1942	8.24959
S-T collaborative work*	.00	25.00	5.3242	7.39392

*S-T: student and teacher

Compared to verbal utterances, students were offered more time to do activities (27.77%). Among all the activities, most were in the collaborative form (18.19%) with the pattern of pair work. This suggested that teachers attempted to conduct more student-centered activities in the class to develop students' skills in collaboration, inquiry and experiments. However, following problems arose in their instruction of student collaborative activities: a. A portion of teachers did have "doubts" in students' ability to conduct and complete the learning tasks. They either intervened as a collaborative partner (5.32%) who provided solutions directly or instructed the students (usually the less competent ones) to seek assistance from other students (18.19%), which lead to only 4.3% of activities done by students themselves. b. When students requested for assistance, the teacher tended to intervene directly to provide solutions without appropriate scaffolds on the collaboration or problem solving. As a result, even when working with their peers, most students were reluctant to take the initiative to do the activities. Under this situation, despite of frequent frequency of students' participated in collaborative activities, the actual opportunities of be involved in the entire set of activities was very few. This would reduce students' motivation and enthusiasm to participate and engage in learning (Sadeh & Zion, 2011). The similar problem was found when the teacher assisted students' individual works.

The impact of teacher subject specialisms was also noted on the organization of students' learning activities. As shown in Figure 3, teachers specialised in physics conducted more students' activities in their lessons (32.08%) compared to their counterparts specialised in chemistry (27.67%) and biology (23.86%). This meant in the lessons delivered by teachers specialized in physics, students usually had more opportunities to participate in learning activities.

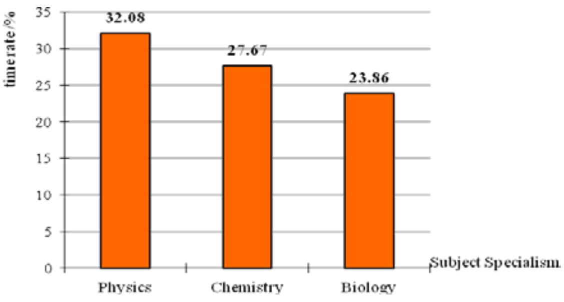

Figure 3. Time distribution of students' activities with different teachers

In conclusion, students were received limited opportunities to build knowledge with the help of the teacher and their group members in either collaborative activities or individual activities, because the teacher intended to be involved in students' activities with the provision of solutions without more exploration on students' misconceptions or current ideas. As a result, students' motivations on engaging in the activities were lower and their interactions with the teacher were not as effective as we expected. Moreover, further exploration on the time distribution on students' activities in classes revealed that teachers who specialized in physics were more positive in creating opportunities for students to do activities. It could be suggested that the teachers balance the time allocated to individual work and collaborative work, as well as to decrease their interventions in students' activities.

Instructional Content

On examining the teaching of instructional content, the most obvious problem was the imbalanced time distribution on each category of these contents. As Figure 4 shows, most class time was spent on teaching within-subject knowledge (49.54%), then the scientific inquiry (19.14%). STS content (6.24%) was largely neglected. The instruction of experiment (2.05%) and cross-subject knowledge (6.77%) received little attention as well. The result implied that most science teachers devoted great efforts to teaching subject knowledge within the same discipline. The teachers had competencies in the integration of within-subject knowledge within or outside their specialisms, but were incapable to incorporate the experiment, STS content and cross-subject knowledge into their class. The reasons were frequently discussed to be related with teachers' content knowledge of integrated science, their teaching skills on the content integration from different subjects, and their own subject specialisms (Harrell, 2010).

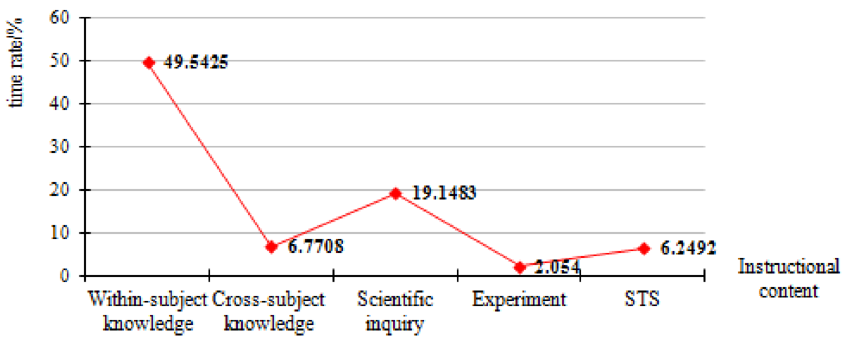

Figure 4. Time distribution of the instructional content

Further analysis indicated significant variations existing in the time distributions of instructional content among teachers of different subject specialism. As shown in Figure 5, teachers specialized in chemistry tended to incorporate much more cross-subject knowledge in their lessons than physics teachers did. However, physics teachers tended to introduce more STS content and integrate experimental content than both chemistry and biology teachers. Yet the latter, compared to the former and biology teachers, introduced more STS content and conducted more experiments. Further conclusions could be drawn that teachers with different subject specialisms spent equivalent time on teaching within-subject knowledge but discrepant time on instructing cross-subject knowledge, scientific inquiry, experiment and STS content.

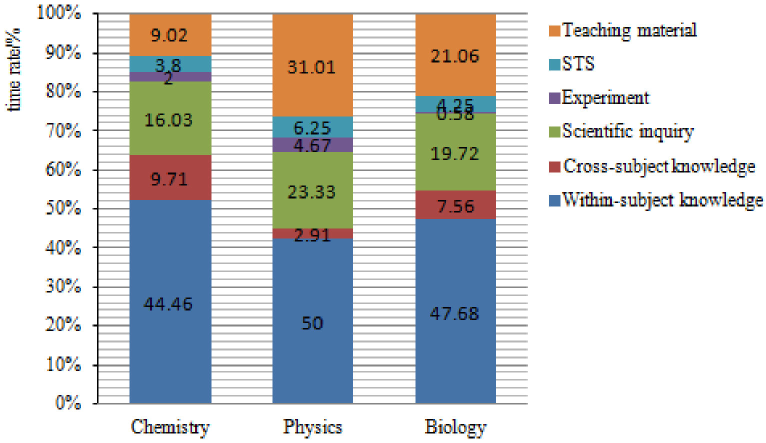

Figure 5. Teachers with different subject specialisms in the teaching of instructional content

Apart from time distribution, we explored the cognitive levels and types of knowledge / skills instructed under each category. This fine-grained analysis better unveiled the problems in the organization of instructional content for integrated science lessons.

Instruction on the within-subject knowledge

As discussed above, the teaching of within-subject knowledge was focalized in lessons. Among all the within-subject knowledge introduced, most were conceptual knowledge (category B) (63.38%), followed by factual knowledge (category A) (22.50%). Both procedural knowledge (category C) (7.06%) and metacognitive knowledge (category D) (7.06%) were only occasionally engaged in solving problem (Figure 6).

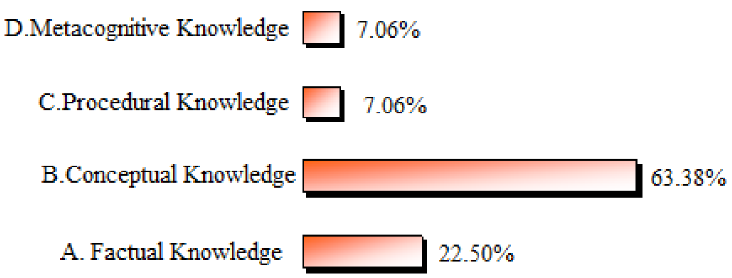

Figure 6. Distribution of each category of within-subject knowledge

Hence, this suggested that the conceptual knowledge was considered as the core of subject knowledge in the integrated science class. The majority of teachers observed were more skillful at teaching conceptual knowledge than other forms of knowledge. Whereas, it also indicated that teachers had significant difficulties towards designing and importing knowledge involving the use of higher cognition skilss. Furthermore, we noticed that though a variety of concepts were introduced in the lesson, these concepts were only processed at the basic level. In these classes, students were found to be required to remember and understand these conceptual knowledge most of the time (56% for “remember” and 42% for “understand”). Application and further analysis of the concepts were rarely required (2% for “apply”). This conclusion still held for students regarding their understanding of factual knowledge. It was observed that there were only a few occasions where factual knowledge was used to interpret or explain scientific phenomena (8% for “apply”). Usually, factual knowledge was merely to be comprehended (28%) and remembered (30%).

For all the teachers, incorporating enough content in their instruction was their priority. Whether the knowledge chosen was appropriate in both depth and scope and whether it was sufficiently processed and practiced were usually not considered. For example, in one lesson, six “core” within-subject concepts had been intensively introduced. However, the teacher extended these “core” concepts by involving other five “relevant” concepts those from the same subject domain. This arrangement of instructional content was problematic as it went beyond students’ cognition load (especially for low ability students) and resulted in ineffective learning.

Overall, under the pressure of remembering and understanding within-subject factual knowledge and the extended concepts, students rarely exercised and applied their new knowledge in problem solving in class. The opportunities of the evaluation and the creation of knowledge in new context were almost absent. Consequently, students had difficulty in constructing sophisticated knowledge and solving high level problems in the new context.

Instruction on the cross-subject knowledge

As we observed, it was clear that science teachers did not share the enthusiasm curriculum developers possess in teaching knowledge outside their specialized discipline areas. Among 36 lessons, there were six during which cross-subject knowledge was absent. This meant almost 16.7% of lessons neglected the integration of subject knowledge from different disciplines. Moreover, when cross-subject knowledge was introduced, it only served as the introduction or background information for interpreting within-subject knowledge, even though the subject domain of cross-subject knowledge was consistent with the teacher’s subject specialism. Such teaching behavior was not within our expectations that teachers might incorporate the cross-subject in the domain of his / her specialism into the lessons in deep way.

The average number of cross-subject concepts incorporated was only two in each lesson, and 87.5% of these concepts were factual knowledge. Teachers had difficulty in teaching the cross-subject knowledge without adequate guidance from the curriculum standards, textbooks and other teaching materials according to their feedback after class. As a result, most students only had a superficial understanding of cross-subject knowledge, particularly the low achieving students.

Instruction on the scientific inquiry

In total, 104 scientific inquiry activities were implemented in the 36 lessons (two or three for each lesson), taking up 19.14% of the total class time. In closer examination of these inquiry activities, there appeared to be a much deeper and more fundamental aspect to the failure of the inquiry activities**.** First of all, as the teachers laid particular emphasis on communication and argumentations in inquiry, collaborative inquiry activities were widely used but in a superficial way. In data analysis, six types of activities involving inquiry skills at different levels and frequency were identified:

- Student collaborative inquiry activity using rudimentary skills (n=21) (C_1),
- Student collaborative inquiry activity using basic skills (n=48) (C_2),
- Student collaborative inquiry activity using integrated skills (n=21) (C_3),
- Teacher individual inquiry using rudimentary skills (n=3) (A_1),
- Teacher-student collaborative activity using rudimentary skills (n=6) (B_1)
- Student individual inquiry activity using rudimentary skills (n=5) (D_1)

Thus, student collaborative inquiry activities (C_2) were conducted most frequently in the class (46%). However, students only practiced basic inquiry skills such as defining variables, drawing tables, making graphs and establishing the relationship of variables. There were collaborative activities where involving the use of rudimentary and integrated inquiry skills (20% respectively), such as making models and defining variables, but much less practiced. Individual student / teacher activities were seldom adopted (less than 10%). Hence, the problem was that although some teachers implemented more than two inquiry activities in one lesson with aim to develop student's inquiry skills, and to help students attain deep understanding of science concepts. These activities usually required applying inquiry skills at low levels. Thus, few opportunities were offered to develop high level inquiry skills (e.g. integrated and advanced skills) in students.

Second, it should be pointed out that though most inquiry activities (86.5%) were achieved via student-student collaboration, these student-student collaborative inquiry processes were usually not free from teacher intervention. Instead of be a guide and facilitator for students' inquiry, the teacher usually acted a leading role in conducting the activities. For example, the teacher tended to judge students' thinking process, offering clarifications when controversies arose and proposing solutions when problems emerged. Thus, the roles mentioned was different from what teachers were suggested to adopt in student-centered inquiry activities, such as being either a motivator, diagnostician, guide, innovator, experimenter, researcher, modeler, collaborator, and learner in different at phases of inquiry (Crawford, 2000). As a result, guided inquiry and open inquiry in which students actually lead the inquiry process and draw self-formulated conclusions were rare occurrences in the lessons observed.

Third, on designing and implementing scientific inquiry, slight differences were identified among teachers with different subject specialisms (Figure 7). Though the acquisition of rudimentary and basic skills was regarded as the main learning objectives by all the teachers, teachers specialized in chemistry and physics paid more attention to the integrated skills compared to the ones in biology. Moreover, physics teachers conducted more inquiry activities than others did. Data analysis showed that teachers with chemistry specialism were specialized in designing and teaching inquiry activities integrating multiple levels of inquiry. Yet for teachers in other subject domains, more efforts should be made to improve their inquiry activity design and implementation skills.

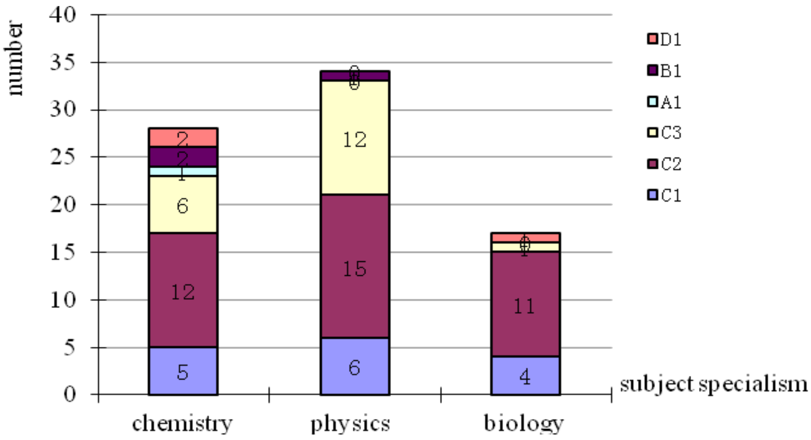

Figure 7. Distribution of different scientific inquiry by teachers with different specialism

Instruction on the STS content

The STS content, along with "basic science concepts and scientific inquiry", had been integral to integrated science instruction as required in the science curriculum standards. Therefore, in a good lesson, attention should also be allotted to the teaching of STS content and scientific inquiry, and not only to the instruction of basic science concepts. However, in the lessons we observed, the value of STS content was usually underestimated. As mentioned earlier, compared to other categories of instructional content, STS content was least integrated. In Figure 8, from No.1 to No.12, the fluctuated line indicates that time distribution of STS content varied over topics. Different teachers dedicated different amount of time for STS content in the same topic, such as No.6 and No.9, No.11 and No.12. No matter what topics were taught, there was no obvious "progressive spiral" of STS teaching (see the dashed line in Figure 8). Only 108 STS concepts were noticed in all lessons.

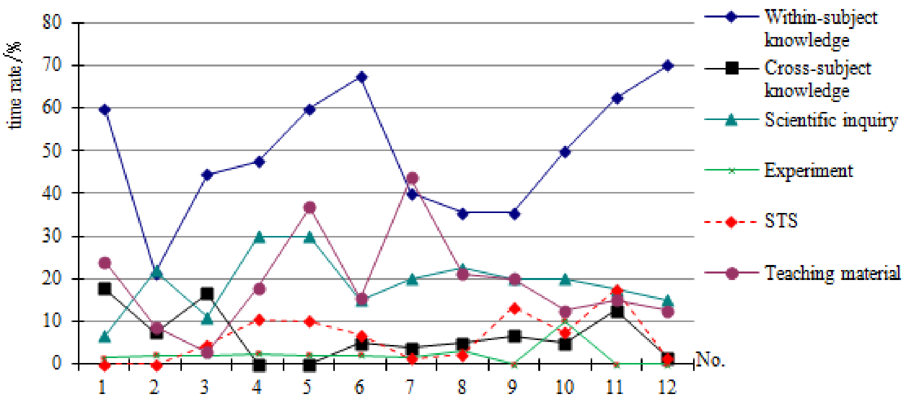

Figure 8. Distribution of instructional content by different teachers

(Note: The number refers to teachers with different subject specialisms who taught the same topics. No.1 and No.2 were on "substance and models of microscopic particles"; No.3 and No.4 were on "neuroregulation"; No.6 to No.9 were on "Sun and Moon" and the last ones were on "circuit".)

Figure 9 presents the patterns of STS integration in lessons. The patterns of STS integration showed that teachers designed and introduced STS content but were not good at integrating these STS content. In most cases where STS content was adopted, the STS content was generally used as background information for assisting with the teaching of within-subject knowledge (64.8%). There was no obvious difference on organizing STS content between teachers with different specialisms. For example, teachers illustrated the "Launching of Chang'e No.1" as the context to introduce the topic of "Sun and Moon". Most teachers only focused on remembering the launching date. The technological aspect which could have more influence on human's future lives was ignored (Chiappetta, 1993). Such approaches actually restricted STS instruction and underestimated the value of STS content. There were occasional incidences where STS content was applied in problematized contexts but few were integrated with scientific inquiry. This means students' inquiry activities were seldom related to their real life.

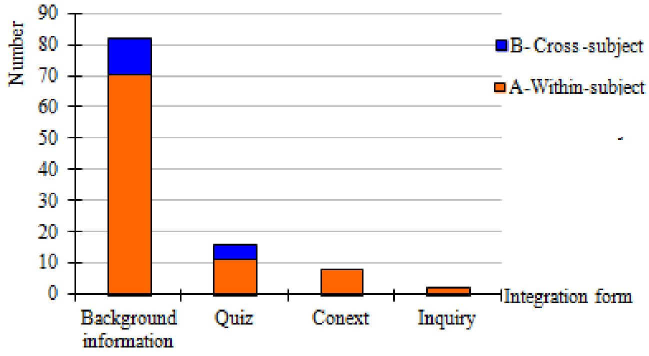

Figure 9. The integration form of the STS content

As STS content was generally viewed as "subordinates" to within-subject knowledge, it was rather expected that students did not attach importance to it. They simply remembered these STS content as factual or conceptual knowledge without further probing and applying them in solving problem. Consequently, these students might feel confused and were hesitant when they were asked to solve the problems related to STS content using higher level skills.

Instruction on scientific experiments

As indicated in Figure 8 above, less attention was paid to scientific experiments than STS content in science lessons. Here, the effect of teacher subject specialism was not obvious. Results indicated that some teachers completely excluded experiments from their instruction. Among the 23 experiments observed, the majority were conducted via student-student collaboration only involving the use of rudimentary skills (75%). For the other 25%, the teacher made the most contribution to completing the experiments. Even in these teacher-guided experiments, only rudimentary skills were incorporated. There was no correlation between the experiment level and teachers' subject specialisms. The findings demonstrated that the teachers might not have sophisticated knowledge of how to design comprehensive scientific experiments to facilitate students to develop high level experiment skills in integrated science.

Conclusions

The main purpose of study is to identify the main factors that hampered the implementation of integrated science curriculum in junior secondary schools in China. Through in-depth classroom observation and data analysis, the problems that negatively impacted the instruction of integrated science are exposed. The findings help to answer the research questions well.

Various challenges encountered by science teachers in the instruction of integrated science were identified to support answering the first research question: 1) In general, most teachers were "good" in instruction organization but poor in distributing time on different types of instructional content. They devoted too much time and efforts to the teaching and integration of within-subject knowledge. Cross-subject knowledge, STS content, scientific inquiry and experiments were reduced to the peripheral, though being equally important. 2) Teachers performed poorly in designing and instructing within-subject knowledge and cross-subject knowledge. In most classes, students were required to remember a considerable amount of conceptual knowledge, but granted few opportunities to practice and evaluate the new knowledge. On the other hand, teachers were hesitant to integrate cross-subject knowledge in their instruction, which reduced the integrative nature of the integrated science curriculum. 3) Teachers' incorporating basic knowledge and low level skills in scientific inquiry and \ or experiments lead to the ineffective instruction on both aspects. 4) Teachers only had superficial understanding on the value of STS content which constrained the integration of SST content in their instructions. They applied and integrated STS content in low level forms, such as background information or reading materials. 5) Teachers could not properly respond to students' answers. 6) Teacher talk usually dominated, leaving little room for students to express their opinions. 7) Though student-student collaborative learning activities were frequently practiced the interaction between the teacher and students were not frequent and effective.

Refer to the second and third research questions, some differences were noted in the integrated science lessons designed and implemented by teachers with different subject specialism. Teachers with different subject specialism held different perspectives on the design and integration of students' activities, scientific inquiry and STS content. Teachers who were specialized in physics conducted more student activities in class, and they used various forms of teaching materials to facilitate students' learning. Compare to other teachers, scientific inquiry and STS content appeared frequent in their lessons. Teachers who specialized in chemistry were more skillful at designing high level inquiry activities and could integrate more cross-subject knowledge.

In conclusion, we highlighted the major challenges the teachers confronted in the instruction of integrated science was that they had limited competency dealing with the integration of with-subject knowledge with other knowledge (e.g. inquiry activities, STS content, scientific experiment), further they lacked knowledge on the nature of STS instruction and teaching strategies on the inquiry and experiments, as well as sophisticated teaching skills on the interacting with students. Their subject specialisms also influenced their design and implementation of the integrated science curriculum.

Implications

Based on our data analysis and literature review, we summarized the reasons why teachers had difficulty in integrating multiple types of contents in instructing integrated science: 1) A lack of content knowledge concerning subjects outside their specialisms; 2) Limited competency in designing and integrating these instructional contents; 3) A lack of awareness to balance different types of contents; 4) Inadequate training and /or a lack of teaching resources. To address these problems, we propose the following approaches to improve the integrated science instructions.

Developing a teacher guide

A teacher guide specifically elaborating and explaining "what to teach" and "how to teach" each topic as listed in the current curriculum should be designed to support teachers' instruction design. In this teacher guide, besides basic content knowledge and pedagogy (Abd-El-Khalick & BouJaoude, 1997), the integration of advanced knowledge and skills concerning different subject domains should be highlighted and be promoted through case study. For example, some scenarios can be developed for teachers to develop deeper understanding on instructions for integrated science through assessment, discussion, reflection, revision, improvement and implementation of the designed lessons. As indicated in previous studies, this can enhance teacher knowledge of integrative content and their practice in the classrooms (Lotter, Harwood, & Bonner, 2007; van Driel, Beijaard, & Verloop, 2001).

Conducting professional training

Apart from these external aids, professional development sessions and training programs should be organized to equip teachers with both awareness and competence to practice student-centered teaching. In professional training, teachers will receive a multitude of teaching techniques that can be adapted or modified to accommodate dynamic classroom teaching and learning. And science teaching strategies that are applicable to both general science courses and specific contents will be provided. Moreover, teachers will be trained more in the design and implementation of the instructional content out of their subject specialisms (Sanders, Borko, & Lockard, 1993). Particularly, the instruction of STS content, scientific inquiry and experiments should be highlighted. More specifically, we suggest teachers should interpret learning objectives from the aspect of inquiry skills discussed in the curriculum standard and design different forms of inquiry activities via changing the levels of inquiry, the types of inquiry skills, and the inquiry agents (Wenning, 2007). As STS content has its peculiar value in science education (Cheek, 1992; Scharmann & McLellan, 1992), teachers should learn to implement a diversity of STS content into their teaching practices to improve the quality of content integration. Further, we propose to integrate STS content into the inquiry activities.

In developing these teacher education programs, teacher individual differences (e.g. Subject specialism) should be taken into account. As we observed, even though teachers had rich experiences in science teaching, they might still have difficulty in integrating subject knowledge out of their subject specialisms. Therefore, teachers should also attend series of professional development programs to acquire content knowledge out of their subject specialism. For example, teachers specialized in biology are required to fill in questionnaire and be interviewed to identify the chemistry knowledge which they may not have deep understanding. Then a specific training session will be conducted for these teachers to learn such knowledge.

Future Work

The above implications also point out the directions for our research at next stage. In further work, besides conducting a survey with science teachers to investigate their attitudes and motivation for integrated science instruction, their instruction skills and areas for improvement, we will make more effort to collect teachers' feedback on integrated science instruction through face-to-face meeting, and to co-design a teacher guide with teachers and science educators. The guide is proposed to provide multiple teaching strategies for science teachers to implement integrated science in an effective way. In particular, both quantitative and qualitative data with a focus on connecting STS content and inquiry activities with subject knowledge will be iteratively collected for modifying and improving the teacher guide throughout trial use. Then, a study will be carried out to investigate how teachers practice teaching strategies as suggested in the teacher guide in the actual classes. In this way, we can constantly explore appropriate or effective ways to deliver the integrated science to students in lower secondary schools.

In summary, confronted with the challenges discuss above, science teacher are still away from mastering integrated science instruction. To address these challenges, multiple parties (including science teachers, school administrator, curriculum specialists and researcher) should work in close collaboration to solve the problems identified and thus improve the quality of integrated science instruction.

Acknowledgements

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Notes

1. In this article, integrated science refers to the science curriculum which is taught in junior secondary schools. The original name of the integrated science was Natural Science in China, which
merged the domain knowledge from the scope of biology, physics, chemistry and geography. In 2001, curriculum reform, the name of Natural Science was changed to Science (Sun, 2010).

2. The textbooks used at the beginning of New China were mostly translations of textbooks from other countries (e.g. Soviet Union). The curriculum had a lot of foreign input. Then a department of People's Education Press took the charge of developing and publishing textbooks for primary schools and secondary schools. During this period 'One Syllabus and One Textbook' was dominant. From 1987, following a series of policies the national government published, the researchers and teachers in Beijing, Shanghai, Zhejiang and Guangdong, started to develop textbooks by themselves. Different versions of textbooks were thus developed and used in different provinces. It was defined as the period of 'One Syllabus and Multiple Textbooks' in China (Zhong, 2009).

3. According to the report of the investigation of science education in China in 2003, integrated science had been covered in all of the junior secondary schools in 13 out of 34 provinces since the start of the 2001 curriculum reform. Approximately 526,000 students participated in this curriculum (Pan, 2005).

4. In China, because the lower status of the integrated science existed for long time, there were few universities that established the major of science education for educating and training pre-service teachers for integrated science before 2001. Therefore, most of the current integrated science teachers specialize in narrow areas within the domain of science, such as biology, chemistry, physics, biology,

biochemistry, etc. Thus, in this article, teachers' subject specialism refers to their major or academic background in universities before they become a formal integrated science teacher in secondary schools.

5. In most parts of China, secondary schools are generally rated as ordinary schools and key schools. In the key schools, most teachers have more sophisticated teaching skills and richer working experience compared to those who teach students in the ordinary schools. The students admitted to the key schools should achieve higher scores of entrance examination than those accepted by ordinary schools. The number of the ordinary secondary schools is much more than the key secondary schools in the same area. So the participants from ordinary secondary school can better represent most of teachers in the same area.

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