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Investigating the Factors that Influence Chemistry Teachers' Use of Curriculum Materials: The Case of China

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ABSTRACT: This paper aimed to explore the factors that influenced teachers' adaptations of the curriculum materials of the new senior secondary chemistry curriculum, a standards-based science curriculum, in China. This study was based on the premise that the interaction of the teacher with curriculum materials in a given social context determined what happens in classroom. An interpretive approach was employed and six chemistry teachers in four senior secondary schools participated in this study. Classroom observation and interview were used as research methods. The data analysis revealed that there were seven factors that led to the teachers' adaptations of curriculum materials, and these factors were teacher's pedagogical content knowledge (PCK), external examinations, time constraint, teaching resources, class size, belief about science, and peer coaching. Among these factors, teacher's PCK, external examinations, and time constraint were the more significant factors that influenced teachers' adaptations of curriculum materials. These factors were discussed in the social contexts of China in the last section of this paper.

KEY WORDS: Chemistry curriculum, chemistry teaching, curriculum materials, curriculum use, interpretive approach

INTRODUCTION

With science curriculum reform coming to a new era in the 1980s and onwards, initiated by the movement of scientific literacy, large numbers of new curriculum materials have been developed around the world (Power & Anderson, 2002). These curriculum materials are usually thought of as being standards-based, which means that they include inquiry as a part of science content, encourage a constructivist and student-centred approach to learning, and require long-term professional development for sustainable implementation (Power & Anderson, 2002). In comparison with traditional curriculum materials, according to Aikenhead (2006), these new curriculum materials can be seen as having humanistic orientation.

Following the global tendency, the latest round of science curriculum reform was initiated ten years ago in China (Wei, 2010). As part of science

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curriculum reform, the official chemistry curricula were established with the national standards of chemistry curriculum at the stages of junior and senior secondary schools promulgated by the Ministry of Education (MoE) in 2001 and 2003 respectively. Subsequently, new chemistry textbooks, aligned with these curriculum standards, have been published and put into use. Researchers have found that these curriculum standards and chemistry textbooks exhibited new features that were akin to those of the standards-based science curriculum materials (Wei & Thomas, 2006; Gao, 2007; Wei & Chen, in press). Based on these studies, it could be concluded that the current chemistry textbooks in China have been transformed into the new type of curriculum materials.

Generally speaking, there exists a basic assumption that standards-based approach to science education is the alignment among instruction, assessment, and the content standards in order to create equal opportunities for students to achieve expected learning outcomes (Herman & Webb, 2007). However, since the standards-based science curriculum requires the teachers to play a substantially different role in the classroom and to change their original beliefs, most teachers are reluctant to implement this kind of curriculum in their classrooms (Aikenhead, 2006). As such, the current situation is that although the standards-based science curriculum materials are available, the implementation of these materials may not be adequate. In fact, the implementation of the new senior secondary school chemistry curriculum has not been going well in China, indicating the problematic interaction between the teacher and the curriculum materials (Wang, 2010).

International researches have showed that teachers' adaptations of this kind of curriculum are influenced by a multitude of factors, including teachers' knowledge, teachers' beliefs and school setting (e.g., Brown, 2002; Roehrig, Kruse, & Kern, 2007). Whereas the existing studies have been conducted in western social context, we have little knowledge about the actual situation of the implementation of standards-based curriculum materials in eastern countries, especially in China, where the school system and the social and cultural context are different from the west. In this paper, we are interested to explore the factors that have influenced the enactment of the new curriculum materials in the classroom in China.

Specifically, this paper was purported to answer the two questions:

1. What factors influenced teachers' adaptations of the standards-based senior secondary school chemistry curriculum materials? and
2. Which were the more significant factors that influenced teachers' adaptations of the standards-based senior secondary school chemistry curriculum materials?

LITERATURE REVIEW

According to Powell and Anderson (2002), curriculum materials refer to the collection of textbooks, teacher's guides, and ancillary materials that are adopted for use in schools for teachers to use while teaching science. As we know, curriculum materials, particularly textbooks, have often determined the taught curriculum for many teachers, especially for young teachers, therefore, they have the potential to initiate and sustain reform in science education (Aikenhed, 2006; Powell & Anderson, 2002). However, curriculum materials themselves cannot generate changes in the classroom. It is dependent on teachers who can use them to enact changes in the classroom. This trait is called the "inert" character of curriculum materials (Powell & Anderson, 2002). In this sense, while recognizing that curriculum materials provide no guarantee of instructional change, Lloyd, Remillard, and Herbel-Eisenmann (2009) argue that teachers are central players in the process of transforming curriculum ideas into reality.

Based on the above assumption, a growing body of literature on teachers' use of curriculum materials appears in recent years, especially in the field of mathematics education (e.g., Remillard, Herbel-Eisenmann, & Lloyd, 2009). Curriculum materials use is different from curriculum materials implementation with the former emphasizing the two aspects: a teacher does not enact the curriculum precisely as envisioned by the designers; the process is not straightforward but involves substantial engagement, interpretation, and decision-making on the part of the teacher (Lloyd et al., 2009). That is to say, when employing the term of "curriculum materials use," the teachers' subjectivity in the process of the enactment of curriculum materials is highlighted in a more intense way than using the term "curriculum material implementation." We take this point as the basic stance in this study. Remillard (2005) argues that curriculum use involves a participatory relationship between the teacher and the curriculum, which in its nature is the interaction between the teacher and the curricular resource. He further claims that this interaction is influenced by a certain context and is shaped by both the teacher and the curriculum. Briefly, according to Remillard (2005), the teacher, the curriculum, and the social context are three main sources that affect the teacher's curriculum use.

The impacts of teacher's knowledge, which is usually composed of subject matter knowledge, pedagogical knowledge, knowledge of context, pedagogical content knowledge (PCK) (Grossman, 1990), on the enactment of reform-based curriculum have been well documented in the literature. For instance, when examining three middle school teachers' interactions with an inquiry-based science unit, Brown (2002) has found that these three teachers' subject matter knowledge and pedagogical content knowledge influenced their teaching and their use of curriculum materials. Manouchehri and Goodman (1998) also show that both of these two types of knowledge have influenced mathematics teachers' evaluation and implementation of an innovative mathematics curriculum. With regard to teacher's beliefs, beliefs on teaching and learning have proved to be the most important influential factors. In an empirical study, examining the implementation of a reform-based high school chemistry curriculum in a large, urban school district in the United States, Roehrig et al. (2007) have found that the teachings of 27 teachers involved in the study are varied in terms of inquiry and the extents of inquiry are clearly related with their beliefs about the nature of teaching and learning. Besides teachers' knowledge and beliefs, researchers have found out other factors that have exerted influences on the use of curriculum materials in the process of curriculum implementation. These factors are listed, not exclusively, as follows: students' abilities and behaviors (Sherin & Drake, 2009; Carlone, 2003), the availability of teaching resources (Haney, Czerniak, & Lumpe, 1996; Nargund-Joshi, Rogers, & Akerson, 2011), time constraint (Keiser & Lambdin, 1996; Bodzin, Cates, & Price, 2003), peers' and administrators' supports (Roehrig et al., 2007; Kauffman, Johnson, Kardos, Liu, & Peske, 2002), the quality of curriculum materials (Vos, Taconis, Jochems, & Pilot, 2011). Obviously, the influence that is exerted on the use of curriculum materials is complex, including a multitude of factors. As such, we agree with Brown (2009) on the complexity of these influences, who has argued that the use of curriculum materials is "determined by both the quality of the designs and their [teachers'] own capacities, as well as features of the context" (p. 22). Thus, in the present study, we have applied the approach of grounded theory to frame a set of factors that have influenced the use of senior secondary chemistry curriculum materials in the classroom in China.

Based on Goodlad (1979)'s classification of curriculum representations and Van Hiele (1986)'s distinguishing on three "levels of thinking and acting", Vos, Taconis, Jochems, and Pilot (2010) have developed a framework to examine the use of innovative context-based teaching materials by teachers in classroom. This analytical framework consists of a nine cell matrix, with "intended curriculum", "perceived curriculum", and "operational curriculum" as the rows, and with "theoretical level", "descriptive level" and "grounded level" as the columns (Vos et al., 2010). The rows, from the intended to operational curriculum, represent a process in which what is intended by curriculum designers in curriculum materials is perceived by teachers and then manifested by them in their classrooms. The columns distinguish concrete teaching activities on the ground level from teaching-learning strategy on descriptive level and aims and vision on theoretical level. This framework has been successfully employed to identify the characteristics of the interaction between innovative context-based teaching materials and teachers that has hindered or facilitated classroom implementation as intended by the designers (Vos et al., 2011).

As mentioned earlier, this study is concerned with how teachers adapted the curriculum materials to meet the needs of their classes, that is, how the intended curriculum is manifested in classroom. Hence, we focus on two types of curriculum representations, i.e., “intended curriculum” and “operational curriculum”. For each curriculum representation, according to the framework of Vos et al. (2010), we focus on three “levels of thinking and acting”, which are “teaching objectives”, “teaching strategies”, and “teaching activities”.

RESEARCH METHOD

If research aims to understand how the intended curriculum can be implemented, as suggested by Anderson and Helms (2001), then conducting research in school settings is necessary. This reason justifies why we employ qualitative research to conduct this study in four senior secondary schools in Nanjing, the capital of Jiangsu province in eastern China. The research paradigm adopted in this study can be classified as the interpretive approach (Erickson, 1986) whose primary goal is to elucidate and interpret the meaning-perspectives of chemistry teachers in their adaptations of the standards-based curriculum materials.

Context

The senior secondary school chemistry curriculum in China comprises required and selective course modules. Required course modules consist of *Chemistry 1* and *Chemistry 2* (*Chemistry 1* precedes *Chemistry 2*), which are required for all senior secondary school students. The six selective course modules are *Chemistry and Daily Lives*, *Chemistry and Technology*, *Particulate Structure and Properties of Substance*, *Chemical Reaction Mechanism*, *Basic Organic Chemistry*, and *Experimental Chemistry*, which are provided for students according to their needs and interests (MoE, 2003). In China, there is a legacy that reformed-based curriculum materials, especially textbooks and accompanying teachers’ guides, are used as a mechanism for school curriculum reforms. The circle of chemistry education in China specially recognizes that textbooks can be seen as the substantiation of the curriculum, and the ideas of the new curriculum should be delivered to practicing teachers through textbooks (Wang, 2010). In practice, chemistry teachers heavily rely on textbooks to determine their teaching content and sequences. Therefore, in the whole process of curriculum reform, no effort has been spared to compile materials and to publish new textbooks. Up to now, there have been three series of senior secondary school chemistry textbooks, which were written according to the national standards of the senior secondary school chemistry curriculum

(MoE, 2003), have passed the official examination, and are currently used in schools.

In Nanjing, the series of chemistry textbooks published by the People's Education Press (PEP), which has been designed as the national education press to produce the syllabi and textbooks directly under the leadership of the MoE since the 1950s, is mandated in all senior secondary schools. This series comprises eight textbooks, each of them representing each of the eight curriculum modules. Units and sections constitute the main body of the textbooks. Each unit has three to six sections, which are the basic teaching units in class. Teaching a section usually takes one to three class sessions (40 minutes for each session). In most cases, some special columns, such as "experiments", "inquiry activities", "scientific perspectives", and "history of chemistry", are inserted in the texts. Main knowledge points are summed in the "summary of this unit". The units end with student exercises. Each textbook is accompanied by one teacher's guide, which is organized in the same sequence as the textbooks. For each unit, the general status and function of this unit, the teaching objectives of this unit, and the time allocation for each section of this unit are provided. For each section, the specific status and the function of the section, and pedagogical suggestions are given. The chemistry textbooks and the accompanying teacher's guides constitute the curriculum materials in this study.

Participants

For the interpretive study, the major principle of sampling is maximizing the scope and range of information obtained (Lincoln & Cuba, 1985). In order to meet this principle of sampling to some extent, we have employed the sampling strategy of "maximum variation" (Marshall & Rossman, 2006) to select the participants in this study. That is to say, teachers are varied in terms of school type[1], teaching experience, and gender. In addition, teachers are also different in the content they taught, e.g., the type of chemistry curriculum (compulsory or elective), and the nature of the content of the unit (theoretical or descriptive chemistry). Finally, six chemistry teachers are invited as participants on a voluntary basis in the present study. Table 1 shows the demographic information for the six teachers.

Among the six chemistry teachers, Ms. Ai has the most years of teaching (25 years) while Mr. Bi has the least (7 years) with the average being 16 years. All of them reported that they had ever participated in in-service training of using the new chemistry textbooks and accompanying teacher's guides, which was organized by PEP in Nanjing. We dare to say that these six teachers are representative of normal chemistry teachers in senior secondary schools in Nanjing or China.

Table 1 Demographic information for the six teachers

Teacher name	School name	School type	Educational background	Teaching experience	Teaching grade
Ms. Ai	Jiankang	Exemplary	BS/Chemistry Education	25 years	Year one
Mr. Bi	Yingtian	Exemplary	BS/Chemistry Education	7 years	Year one
Ms. Chang	Yingtian	Exemplary	BS/Chemistry Education	20 years	Year two
Mr. Dong	Moling	Ordinary	BS, ME/Chemistry Education	14 years	Year one
Mr. En	Tianjing	Ordinary	BS, ME/Chemistry Education	12 years	Year one
Mr. Fang	Tianjing	Ordinary	BS/Chemistry Education	15 years	Year two

Note. Both teachers' and schools' names are anonymous.

Data Collection

For each teacher, the research are focused on a whole unit to obtain a relatively complete picture of the related curriculum materials and the teacher's practice. The details of the curriculum materials we observed for each teacher are shown in Table 2.

For each unit, the teaching objectives, teaching strategies in the teacher's guides, and the special column, "inquiry activity", in the textbooks, were selected as the components of the intended curriculum. To find teachers' adaptations of the intended curriculum, and the factors that led to these adaptations, classroom observation and interviews were used as research methods. Each teacher was observed through the whole unit, which lasted approximately from two to four weeks. During each observation, the first author took field notes, recording what teaching strategies were used and how the special column, "inquiry activities", was implemented in the classroom. All the observations were also videotaped by using an electronic camera. In addition, semi-structured interviews were conducted after each section. The interviews were focused on these questions: (1) what were the teaching objectives the teacher set for the section? If they were different from those set in the teacher's guide, what were the reasons?; (2) If the teaching strategies the teacher used were different from those set in the teacher's guide, what were the reasons?; (3) When "inquiry activities" are set in the textbook, but the actual procedures (experiments, activities) in classroom or lab were different from those in the textbook, what were the reasons? The interviews were audio-taped, and then transcribed into Chinese after the interview. The transcripts were returned to each of the teachers for their confirmation or criticism. Overall, classroom observations were data sources of "teaching strategies" and "teaching activities" in operational curriculum, and interviews were data sources of "teaching objectives" in the operational curriculum and teachers' explanations for adaptations.

Table 2 Curriculum materials used by the six teachers

	Unit	Sections	Module
Ms. Ai	Metals and their compounds	1. Chemical properties of metals 2. Several important metallic compounds 3.Metallic materials with wide usages	Chemistry 1
Mr. Bi	Chemical substances and changes	1.Classifications of substances 2.Ionic reactions 3. Oxidation and reduction reaction	Chemistry 1
Ms. Chang	Basic organic substances in lives	1.Grease 2.Saccharide 3. Protein and nucleic acid	Basic Organic Chemistry
Mr. Dong	Chemistry reactions and energy	1.Chemical energy and thermal energy 2.Chemical energy and electric energy 3.The rate and the limitation of chemical reaction	Chemistry 2
Mr. En	Chemistry reactions and energy	1.Chemical energy and thermal energy 2.Chemical energy and electric energy 3.The rate and the limitation of chemical reaction	Chemistry 2
Mr. Fang	Ionic equilibrium in aqueous solution	1. The ionization of weak electrolytes 2.Water ionization and the acidity and alkalinity of solution 3. Hydrolysis of salts 4. The dissolution equilibrium of insoluble electrolytes	Chemical Reaction Mechanism

Data Analysis

In the present study, data analysis comprised two steps. In the first one, classroom observations and the interviews about teaching objectives were used as sources to compare with curriculum materials to identify the discrepancies between the operational and intended curricula at the three levels of "teaching objectives", "teaching strategies", and "teaching activities". The analysis of this step provided the clues for us to explore the reasons that determined teachers' adaptations of curriculum materials.

In the second step, the interviews about teachers' explanations for adaptations were used as sources to trace the factors that led to teachers' adaptations of curriculum materials. In qualitative research, the coding was usually grounded in the data (Glaser & Strauss, 1967). In this study, the coding was derived from the interviews with each teacher. Specifically, we first read the transcripts of the interviews line by line repeatedly to get ourselves familiarized with these data, and then we wrote down the background information about the context of the discussion on every excerpt and used open coding techniques to characterize the interview data to construct initial codes. 13 initial codes were found while analyzing the quotations. These codes were (1) knowledge about instructional strategy, (2) knowledge about teaching objective, (3) knowledge about students' prior knowledge, (4) knowledge about requirements for learning new knowledge, (5) irrelevance with examination, (6) focal point in examination, (7) insufficient teaching time, (8) saving teaching hours, (9) lack of experimental equipment, (10) insufficient laboratory, (11) big size of class, (12) teacher's belief about science, (13) colleague's suggestion. Furthermore, different initial codes were compared and integrated to generate the different types of factors that led to the adaptations. For example, according to Magnusson, Krajcik, and Borko (1999), science teacher's PCK includes orientations toward teaching science (knowledge about the purposes for teaching science at a particular grade level), knowledge of science curriculum (knowledge about mandated goals and objectives, and specific curricular programs and materials), knowledge of assessment in science (knowledge about dimensions of science learning to assess and methods of assessment), knowledge of instructional strategies (knowledge about specific strategies that were useful for helping students comprehend specific science concepts), and knowledge of students' understanding of science (knowledge about students' prior knowledge, requirements for student learning, and areas of student difficulty). Thus, the first four codes were combined into the factor "teacher's PCK". Finally, seven factors were identified, and they were teacher's PCK, external examinations, time constraint, teaching resources, class size, belief about science, and peer coaching. Moreover, in order to answer the second question, we tabulated the data in two ways.

a. The various factors that led to the adaptations at the three levels were tabulated to identify the numbers of teachers that each factor exerted influence at each level.
b. These factors were tabulated to identify how many teachers were influenced by each factor.

To ensure reliability, the two authors analyzed the data together. Whenever disagreements occurred at any stage of analysis, we discussed our differences, eventually agreeing on one's ideas or a merging of both ideas.

RESULTS

The Factors That Influenced Teachers' Adaptations

We have identified seven factors that led to teachers' adaptations of intended curriculum. These factors are PCK, external examinations, time constraint, teaching resources, class size, belief about science, and peer coaching. In this section, we will describe these factors one by one.

Pedagogical Content Knowledge

Pedagogical content knowledge (PCK) is different from subject matter knowledge and knowledge of general pedagogy; instead, it is knowledge of how to teach specific content in specific contexts (Shulman, 1986). In this study, PCK is found to be one of the factors that has led to teachers' adaptations of curriculum materials. Some instances are provided here.

Comparing the teacher's operational curriculum with the intended curriculum at the level of "teaching objectives", , we found that Ms. Chang did not mention the teaching objective in her lesson, which was suggested in the teacher's guide as: "to enable students to further experience the processes of investigating chemical substances, understand the meaning of scientific inquiry, learn the basic methods of scientific inquiry, and enhance the abilities of doing scientific inquiry through the investigative experiments of monosaccharide, disaccharide, and polysaccharide" (PEP, 2007a, p. 84). When talking about this objective, Ms. Chang gave the following comments:

> *In my mind, I don't consider them [referring to the experiments in this objective] investigative experiments, as our students have known the results a long time ago. They knew the reducibility of fructose, sucrose, maltose from their biology classes. They had known it! They [experiments] would only be funny for them [students] if we did these experiments in our class. Did we really cultivate students' abilities of scientific inquiry? No!*

As explained by Ms. Chang, students had already known the results of these experiments from their biology classes, so it was not necessary to conduct such investigative work in the chemistry class. This adaptation was based on the teacher's knowledge about students' prior knowledge.

In the section of "oxidation and reduction reaction" in the unit "chemical substances and changes", the teacher's guide suggests teachers to adopt the "discussion" strategy "to engage students in the process of inquiry oriented learning" (PEP, 2007b, p.28). However, in the actual process of teaching, Mr. Bi did not adopt this kind of teaching strategy. In the interview, he gave the following explanation:

> *I don't think the discussion strategy should be involved in the teaching of chemical concepts. As I see, what is oxidation or what is reduction, it is a scientific definition and it is defined by people. It does not need to be discussed.*

According to Mr. Bi, the fact that he did not adopt the "discussion" strategy was attributed to his thought that this strategy did not match the content he taught. This adaptation was influenced by his knowledge about instructional strategies.

In the section "hydrolysis of salts" in the unit of "ionic equilibriums in aqueous solution", there is an "inquiry activity", titled "inquiring factors that affect the degree of hydrolysis of salts" (Song, 2007a, p.57). However, Mr. Fang disregarded this "inquiry activity" arranged in the textbook. When asked why he did not carry out this activity in his class, he gave the following comments:

> *As you know, in the first section, we analyzed the ionization equilibrium shifting of weak electrolytes, and in the second section, we analyzed ionization equilibrium shifting of water. Based on these lessons, it has been clear that it [hydrolysis equilibrium shifting] is a shifting of chemical equilibrium in its nature. That is to say, it is similar to the previous two sections. The affecting factors include the temperature, the concentration of substances, and additional acids, bases, and salts. In its nature, this lesson also indicates the issue of chemical equilibrium and its shifting. Students have already known these pieces of knowledge. So, I say that it is not necessary to do these kinds of things in this section.*

As indicated in the above excerpt, he did not adopt this "inquiry activity" because he thought students had already acquired this knowledge. Thus, engaging the students in this activity was unnecessary. This adaptation was based on his knowledge about students' prior knowledge.

External Examinations

External examinations, particularly university entrance examinations, have proved to be a factor that has led to teachers' adaptations of curriculum materials. The notion of the "examination" mentioned by teachers mainly refers to university entrance examinations, which are usually held at the beginning of June each year at the provincial level in China. Some instances are provided here.

In the unit of "chemical substances and changes", at the level of "teaching objectives", Mr. Bi did not take the objective of "to let students recognize the important role that the method of classification plays in chemical research and learning" (PEP, 2007b, p.21) suggested in the teacher's guide as his objective. Mr. Bi gave the following explanation:

> *Frankly, our teaching is related with the examination. As you know, the examination is important for us. If it is not included in the examination, we would not take it seriously. You can say that our teaching is examination oriented. I admit this is a fact.*

As shown in the excerpt, the reason that Mr. Bi did not take the method of classification as his objective was that this kind of knowledge is not included in the external examinations.

At the level of "teaching strategies", Mr. Dong added "exercise"-"making students complete the exercises related to galvanic cell" in the section of "chemical energy and electric energy" in the unit of "chemistry reactions and energy". For this adaptation, he gave the following comments:

> *As you know, galvanic cell is a focal point in the examination. Therefore, I arranged the section of exercise to solidify students' skills and knowledge. I hope that the exercise can detect students' misunderstanding about galvanic cell and thus I can make some correction and remedy in the subsequent lessons.*

As explained by Mr. Dong, he added the strategy of "exercise" because galvanic cell is a focal point in the external examinations.

Time Constraint

Chemistry was taught in two to four class sessions per week in these four schools where we conducted this study. Time constraint was often mentioned by chemistry teachers to be a factor that led them to adapt curriculum materials at the levels of teaching objectives, strategies, and activities. Some instances are provided here.

As suggested in the teacher's guide, one of the objectives in the unit of "chemistry reactions and energy" is "to be aware of the applications of the transform of chemistry energy to thermal energy in industries and daily lives" (PEP, 2007c, p.15). However, Mr. En did not take this as his teaching objective. He gave the following comments:

> *Of course, we should have taken this as our objective in the view of chemistry education at a higher level so as to help students recognize*

> *this kind of energy change in nature. However, as you know, we only have two sections one week; we do not have much time to cover these things.*

According to Mr. En, the reason that he disregarded this objective was that there was not enough time to cover these things. This belonged to the factor of time constraint.

At the level of "teaching strategies", in the section of "chemical energy and electric energy" in the unit of "chemistry reactions and energy", Mr. En disregarded the strategy of "inquiry"-"to engage students in the investigative experiment of galvanic cell and let students tentatively master the manipulative and observational skills" (PEP, 2007c, p.26)suggested in the teacher's guide. For this adaptation, Mr. En explained in this way:

> *The main reason is that time did not allow us to do this [referring to "inquiry"]. If we did it, it would take us a long period of time. It is too time consuming! As you know, we have fewer lesson hours in the chemistry class and we could not afford to do it.*

As explained by Mr. En, the fact that he did not adopt the strategy of "inquiry" was due to time constraint.

In the section of the "hydrolysis of salts" in the unit of the "ionic equilibriums in aqueous solution", for the "inquiry activity", titled "relationship between salt composition and acidity or alkalinity of salt solution" (Song, 2007a, p.54), Mr. Fang adapted the first procedure (determining acidity or alkalinity of salt solution) as a teaching demonstration. Students accomplished the other two procedures in groups. Mr. Fang explained the reason for this adaptation as follows:

> *We must say that the best way for practical work is requesting students to do it by themselves. For the teaching effect, the way students conduct experiments is better than that of teacher demonstration. At least, students can observe the phenomena more clearly in student experiments than in teacher demonstrations. However, in view of teaching time, we should save our teaching hours. You know, we don't have enough hours for chemistry classes. We had no choice but did teacher demonstration.*

As indicated above, the reason that Mr. Fang replaced group work with teaching demonstration was to save time. This decision was influenced by time constraint.

Teaching Resources

As we know, chemistry teaching usually needs equipment and facilities to support. Especially, more equipment and facilities are needed in the new curriculum to conduct student-centered practical work. This might be the reason that teaching resources were mentioned by chemistry teachers to adapt curriculum materials.

At the level of "teaching objectives", Mr. Fang did not mention the objective of "letting student master the method of measuring the pH value of aqueous solution" (PEP, 2007d, p.54) suggested in the teacher's guide. He gave the following explanation:

> *I originally had planned to let students to use the pH meter to measure the pH value of aqueous solution. However, there is no pH meter in this campus. In the other campus, we do have pH meters, but we have failed to move them to this campus timely.*

According to Mr. Fang, the fact that he failed to realize this objective was due to the lack of the experimental equipment.

In the unit of "chemical substances and changes", there is only one "inquiry activity", which is set in the section of "classifications of substances". The purpose of this activity is to let students know the properties of the colloid (Song, 2007b). Mr. Bi does not require students to conduct the experiment in groups. Instead, he conducts the experiment as a teaching demonstration. He explains as follows:

> *You know, we have many parallel classes in this year and the progresses of classes are similar, that is to say, dozens of classes had to conduct this activity simultaneously. Our laboratories were unable to accommodate so many classes.*

As shown in the excerpt, students were not engaged in this activity because the teaching resources were limited.

Class Size

Class size refers to the number of students in a class. In China, there are usually over 50 students in a chemistry class. In this study, class size is mentioned by Ms Ai as a reason to adapt curriculum materials.

In the section of "chemical properties of metals", Ms. Ai did not adopt the teaching strategy of "inquiry"-"to organize inquiry activities and to make students experience the processes of scientific inquiry" (PEP, 2007b, p.39) suggested in the teacher's guide. She gave the following explanation:

> *Of course, experiencing the processes of scientific inquiry is important for students, but in such a big size of class, this is only dependent on the opportunities. Frankly, we do not do scientific activity in every lesson. That is to say, inquiry activity is not always possible in such an*

environment.

According to Mr. Ai, the fact that she did not adopt the strategy of "inquiry" was due to the large number of students in her class.

Belief about Science

Teachers' belief about science has proved to be a factor that leads teachers to adapt curriculum materials. In this study, we have found that Ms. Chang's adaptation of curriculum materials at the level of "teaching objectives" is due to her belief about science.

In the section of "saccharide" in the unit of "basic organic substances in lives", Ms. Chang added a teaching objective concerning the historical story of the discovery of the structure of glucose. In the interview, she gave the following explanation:

> *As you know, the textbook only provided a conclusion about the structure of glucose but not the process of the discovery. That is, it ignored the history of this discovery. As such, students' knowledge about glucose is segmented and but not complete. This is the defect of the textbook. So I added the history of this discovery.*

As indicated above, the fact that Ms. Chang added this teaching objective was attributed to her view that science is a historical process. This adaptation was based on the teacher's belief about science.

Peer Coaching

Peer coaching refers to a process of cooperation between two or more colleagues in which they exchange ideas, attempt to implement these ideas, reflect their own teaching practice, and so on (Van Driel, Beijaard, & Verloop, 2001). In China, peer coaching often occurs among teachers in the process of lesson plans. In this study, we have found that Mr. Bi's adaptation of curriculum materials at the level of "teaching strategies" has come from peer coaching.

In the section of "oxidation-reduction reaction" in the unit of "chemical substances and their changes", at the level of "teaching strategies", Mr. Bi added the strategy of "experiment"- "demonstrating the experiment of galvanic cell". He mentioned that this addition came from a colleague's suggestion. The following were his comments:

> *This is my first time to do the experiment of galvanic cell. I never did it before. A leading teacher in our group said the effect of doing this experiment is good. So, I followed him and did this experiment in my class.*

The More Significant Factors

As we have known, there are seven factors that influenced teachers' adaptations at three levels, "teaching objectives", "teaching strategies", and "teaching activities". We are interested to know how many teachers are influenced by each factor at each level. The results are shown in table 3.

Table 3 The factors leading to the discrepancies between the operational and intended curricula at the three levels

	PCK	External examinatio	Time constraint	Teaching resources	Class size	Belief about	Peer coaching
Teaching objectives	4	3	1	1	0	1	0
Teaching strategies	6	4	3	0	1	0	1
Teaching activities	4	0	3	1	0	0	0

Note. Numbers in the table represent the number of teachers (0≤n≤6)

As indicated in Table 3, at the level of "teaching objectives", PCK influenced four teachers, external examinations influenced three teachers, and time constraint, teaching resources, and teacher's belief about science influenced one teacher respectively. At the level of "teaching strategies", PCK influenced six teachers, external examinations four teachers, time constraint three teachers, and class size and peer coaching one teacher respectively. At the level of "teaching activities", PCK influenced four teachers, time constraint three teachers, and teaching resources one teacher.

As presented in the above section, it can be seen that the seven factors have influenced the six teachers differently. The influences of each factor on each teacher are shown in Table 4.

Table 4 The factors leading to the discrepancies between the operational and intended curricula for six teachers

	PCK	External examination	Time constraint	Teaching resources	Class size	Belief about science	Peer coaching
Ms. Ai	√	√	√		√		
Mr. Bi	√	√		√			√
Ms. Chang	√					√	
Mr. Dong	√	√	√				
Mr. En	√	√	√				
Mr. Fang	√	√	√	√			

As indicated in Table 4, PCK influenced all of the six teachers, external examinations five teachers, time constraint four teacher, teaching resources two teachers, and class size, teacher's belief about science, and peer coaching one teacher respectively.

Taking Table 3 and Table 4 into consideration together, we can see that teacher's PCK, external examinations, and time constraint are the more significant factors that influenced teachers' adaptations among the seven factors. That is to say, these three factors are the key ones that led to teachers' adaptations of curriculum materials.

CONCLUSION AND DISCUSSIONS

In this paper, we have disclosed seven factors that have led to chemistry teachers' adaptations of curriculum materials, and these factors are teacher's PCK, external examinations, time constraint, teaching resources, class size, belief about science, and peer coaching. If teacher's PCK and teacher's belief about science belong to personal factors, other factors identified in this study can be classified as contextual factors. As argued earlier in this paper, the use of curriculum materials occurs in a social context and is usually influenced by many factors within and beyond the education system (Remillard, 2005; Brown, 2009). In this sense, the seven factors identified in this study have provided a specific scenario that has portrayed the interaction between the teacher and curriculum materials in the process of the implementation of the standards-based science curriculum in the social context of China. It should be noted that although some of these seven factors have been dispersedly identified in the previous studies, such as teacher's PCK (Brown, 2002), time constraint (Bodzin et al., 2003), teaching resources (Haney et al., 1996; Nargund-Joshi et al., 2011), and peer coaching (Roehrig et al., 2007), we holistically reveal these factors in a study for the first time.

Furthermore, we have found that teacher's PCK, external examinations, and time constraint are the three key factors that influenced teachers' adaptations. Given the facts that almost all of the participant in this study can be thought of as experienced teachers (with seven or more years of teaching chemistry) and practicing teachers are not substantially involved in the actual process of curriculum designing in China (Liang, 2002), it is not surprising to have found that teacher's PCK is one of the key factors. This finding also echoes the vision emphasized in the literature, that is, the personal factors of teachers exert important influences on the use of curriculum materials (Remillard, 2005). Based on this finding, we suggest that more interactions needs to be undertaken with experienced science teachers in designing curriculum materials and in preparing textbooks. The PCK of these experienced teachers needs to be represented in the curriculum materials and science textbooks. Specifically, setting teaching objectives, recommending teaching strategies, and designing teaching activities need to consider and link to the PCK of teachers. In this way, the objectives, strategies, and activities in the curriculum materials can be feasible and useful in the classroom. However, teachers have experiences of teaching doesn't mean they have rich PCK when it comes to reform-based practices. If these six teachers have undeveloped PCK about the implementation of the standards-based curriculum, then more teacher professional development needs to be provided and associated with the development and implementation of curriculum materials.

As we know, the humanistic content and scientific inquiry cannot be easily tested in the large-scale written examination such as the university entrance examination. Due to the inherent defects of this kind of examination, external examinations (university entrance examination) is an important factor that often impedes the implementation of the standards-based science curriculum in developing countries (Coll & Taylor, 2008), especially in China, where the "culture of examination" is prevalent (Gu, 2004). As an ancient Chinese idiom says, "although studying silently for ten years, once you are successful, you will become well-known in the world". Young people, especially those that came from average or poor families, are encouraged by this kind of culture to study diligently and consistently to raise their social and economic status. Success in external examinations, particularly the national university entrance examination, means that one can have a good expectation of high income after graduation from university; students' achievements in public examinations usually serve as an important indicator of schools' reputations; teachers take the responsibility to ensure students to achieve the exam requirements (Gao & Watkins, 2002). Therefore, teachers usually disregard the humanistic content and scientific inquiry in their teaching practice and give their teaching emphases to the knowledge and skills that can be tested in the paper examination so as to help their students to achieve high scores. By contrast, there is little literature which has proved that external examinations hindered the implementation of the standards-based science curriculum materials in western developed countries. This difference between the east and west has confirmed the argument that culture context have important influences on the implementation of science curriculum (Coll & Taylor, 2008).

Compared with the traditional chemistry curricula, which is usually subject-centered and teacher-centered, the new chemistry curriculum involves more humanistic content and more strategies and activities related with scientific inquiry. As such, teaching this kind of science curriculum is often time consuming. Therefore, time constraint identified as a key factor in this study is understandable. An interesting finding is that the time constraint has influenced the three teachers, Mr. Dong, Mr. En, and Mr. Fang, all of whom come from ordinary schools. In ordinary schools, students are not as able as students in exemplary schools. Thus, teachers have to spend more time on exercises and thus have less time to teach humanistic content and to carry out scientific inquiry activities. This fact can be considered an example of the influence of social context on the implementation of the new chemistry curriculum.

We confess that it is not our purpose to evaluate which factors impel or impede the implementation of the standards-based science curriculum in the classroom. However, while taking a closer look at these seven influencing factors, it can been seen that at least there are four factors that impede the actual implementation of the standards-based senior secondary chemistry curriculum in the classroom, and they are external examinations, time constraint, teaching resources, and class size. But there is only one factor – teacher's belief about science (Ms. Chang's view that science is a historical process) in this study that can be seen as an impelling factor that had positive influence on the implementation of the new chemistry curriculum. It is obvious that there is an unbalance between the impelling forces and impeding forces in dealing with the tension between the traditional and standards-based science curricula at the level of the classroom. This may partially explain the current situation of the implementation of the new chemistry curriculum in China. This problem needs to be explored in the future studies.

NOTES

[1] In China, senior secondary schools are classified into exemplary schools and ordinary schools. Exemplary schools have more resources and are able to recruit more competent students than ordinary schools.

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