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Science Curriculum Reform in Post-Compulsory Education in the People's Republic of China: The Case of Senior Secondary School Chemistry Curriculum

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ABSTRACT *As part of the latest round of curriculum reform in the People's Republic of China, school chemistry curriculum is experiencing a transition. A major feature of this curriculum reform is that the form of national standards has been used to construct the official document of secondary school chemistry curriculum. This paper focused on accounts of the social background, producing process, rationale, structure of the national standards of senior secondary school chemistry curriculum (SSSCC). In order to discern the differences of the new SSSCC with the traditional ones, a comparison was made between the national standards and the previous syllabi in terms of curriculum intentions and contents. The experiences and problems involved in developing the national standards of the SSCC are discussed in the final part of this article.*

KEY WORDS: *Chemistry curriculum, science curriculum, curriculum reform, scientific literacy.*

Introduction

Since the late 1970s, great social and economic changes occurred in the People's Republic of China. The enterprise of education, especially basic education (the equivalent to K-12 grades in the American schooling system), has been considered inadaptable to the social and economic development in this country. Under this background, a latest round of curriculum reform was initiated in 1999 after a long period of ferment (Huang, 2004). The ambition of this reform was to raise the quality of education in order students to meet the challenges of new times. Specially, cultivating students' spirits of creativity and practical abilities has become the central goal of this round of curriculum reform (CCCPC & SC, 1999). The objectives and strategies of this curriculum reform are provided in the *Outline of Curriculum Reform of Basic Education* (MoE, 2001a), which has served as the guidelines for the reform. According to this outline, the curricula of primary schools (1-6 grades) and junior secondary schools (7-9 grades), both of which constitute the nine-year compulsory education system, are designed as a whole, while the curriculum of senior secondary schools (10-12 grades) is separately designed. It is required in the outline that curriculum standards of subject curricula, such as chemistry, replace the syllabi, the link between the national teaching programs and the textbooks[1]. As with the previous syllabi, it is claimed that curriculum standards function as the "basis of writing of textbooks, practical teaching, teaching evaluation, and examinations" (MoE, 2001a, p.4). This paper is focused on accounts of the genesis, rationale, structure of the national standards of senior secondary school chemistry curriculum (SSSCC), and comparison with the previous syllabi of the SSSCC with the aim of presenting the efforts made in a developing country to reform traditional science curricula in the form of curriculum standards at the stage of post-compulsory education.

As stipulated in the *Program of the Senior Secondary School Curriculum Reform* (PSSSCR, MoE, 2003a), the senior secondary school curriculum is composed of eight fields of study: language and literature, mathematics, humanities and social studies, natural sciences, technology, arts, physical education and health, and practical activities. Each field of study consists of one or more subjects, which are similar in their nature. For instance, the field of natural sciences consists of four science subjects that are physics, chemistry, biology, and natural geography. Each subject consists of several course modules, which are interrelated with each other but have their own structure and emphases. The hierarchical relationship among these three components of the senior secondary school curriculum is shown in Figure 1. It is required in the PSSSCR that each secondary school student should study all of these eight fields of study within every year.

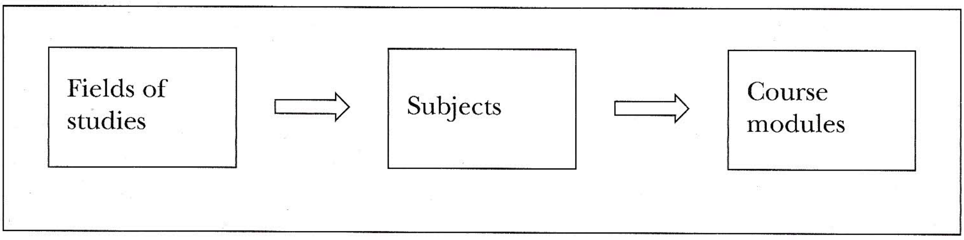

Figure 1. The hierarchical relationship among three components of the senior secondary school curriculum

Genesis of the New SSSCC

The chemistry curriculum reform included two stages. The first stage was on the level of junior secondary schools, while the second was on the level of senior secondary schools. The first stage began at the early 1999 and ended in June 2001 with the national standards of junior secondary school chemistry curriculum formally issued by the Ministry of Education (MoE, 2001b; Wei & Thomas, 2005). The

1. In China, the Ministry of Education (MoE), or the State Education Commission (SEdC) from 1985 to 1998, has the highest authority in relation to planning and designing school curricula. Specifically, the Department of Basic Education (or Primary & Secondary School Education) in the MoE is directly responsible for designing the national teaching program, which specifies the overall curriculum organization and the timetable arrangement for school subjects. Once the overall teaching program is finalized, the teaching syllabus of each subject curriculum is detailed, and the textbooks are produced.

project of designing the national standards of senior secondary school chemistry curriculum was initiated in the autumn of 2001. This marked the startup of the second stage of secondary school chemistry curriculum reform. The designers were the same persons involved in producing the national standards of junior secondary school chemistry curriculum, and most of them were young chemistry educators in teachers' universities across the country. After one and a half years, a draft document was formed at the end of 2002. In January 2003, this draft was approved by an expert commission assigned by the MoE, which was composed of academic chemists and senior chemistry educators in universities. This draft was modified in the light of the commission's suggestion and advice afterwards. The national standards of senior secondary school chemistry curriculum (for brevity, called the 'national standards of the SSSCC' in this paper) was issued by the MoE for trial use in practice (MoE, 2003b).

The genesis of the national standards of SSSCC mainly came from two sources. The first source was the criticism on the traditional SSSCC. A survey on the status of senior secondary school chemistry teaching was conducted by the designers in the end of 2001. Almost 1,000 senior secondary school students were involved in this survey. The results of this survey were summarized by the designers (Wang & Wang, 2004) who stated that: (1) students lack interest in learning chemistry; (2) classroom instructions are mainly oriented towards the university entrance examination; (3) chemistry teachers and textbooks are perceived by students as the authorities of knowledge; (4) instruction is isolated from the real social situations; (5) the teacher-centered instruction prevails in chemistry classrooms; (6) students' initiatives of learning have not stimulated; (7) students lack good habits of conducting chemical experiments; (8) textbooks are not interesting for the majority of students. As for the curriculum, according to the designers, these identified problems were manifested in the four aspects, which should be resolved in the new SSSCC: (1) the objectives of knowledge and skills were over emphasized; (2) the difficult, trivial, obscure, and outdated contents did exist in the senior secondary school chemistry curriculum; (3) students' learning was absolutely passive – learning by rote was the most common mode; and (4) curriculum evaluation was equated with achievement examination, and, moreover, the university entrance examination has overwhelmingly been dominating in teaching practice (Wang & Wang, 2004). Especially for the targets of the traditional SSSCC, the designers believed that previous curriculum reforms and innovations were only concerned with the needs of the more able students who would continue to study chemistry or related fields in their tertiary education, but badly neglected the needs of students who did not plan to continue studying chemistry. According to a designer, how to simultaneously satisfy these two kinds of needs was a major concern in the initial stage of designing the new SSSCC (personal communication with a designer of the new SSSCC).

The other source of the new SSSCC came from science curriculum development in western countries. Prior to designing the national standards of the SSSCC, as preparatory work, the designers had both intensively and extensively read varied kinds of chemistry programs, textbooks, national standards of science or chemistry imported from western countries, Taiwan, and Hong Kong. These materials included *Science for All Americans, Chemistry in Community* from the USA, and *Salters'*

Chemistry programs, *Science and Technology in Society,* and *Science in National Curriculum* from the UK (Wang & Wang, 2000). When reviewing these materials, the designers recognized that scientific literacy had served as an overarching goal of science education across the world. As for the chemistry curriculum in China, they believed that embodiment of scientific literacy into chemistry curriculum should be accomplished by specifying three dimensions of science teaching objectives, that is, 'knowledge and skills,' 'processes and methods,' and 'emotions, attitudes, and values' (Wang & Wang, 2004). For the contents and organization of the national standards of chemistry curriculum, the common features of these documents and programs were summarized as follows in a progress report: (1) a thematic approach is used to construct the curriculum contents; (2) scientific inquiry is used as a learning mode for students; (3) subject knowledge is presented in various contexts; and (4) social problems are prominent in science curriculum (Wang & Wang, 2000). Several features were also identified as the tendency of chemistry curriculum at the level of senior secondary schools in the world. Firstly, senior high school chemistry curriculum should be optional. That is to say, it should meet the needs of differently oriented students. Secondly, the contents of senior secondary school chemistry curriculum can be organized in different ways: some may focus on chemical concepts and theories, others may emphasize the functions of chemical experiments, still others may be more oriented to social practices. Thirdly, chemical experiments are given much more emphases in varied types of senior secondary school chemistry curriculum (Wang & Wang, 2004). Almost all of these perceived features and characteristics have been reflected in the national standards of the SSSCC.

Rationale of the new SSSCC

It is argued in the national standards of the SSSCC that chemistry curriculum is an integrated component of science education and plays important roles in further raising the level of scientific literacy of senior secondary school students. Furthermore, it is asserted that the "SSSCC is linked up with the chemistry or science curriculum at the stage of compulsory education[2] and therefore it is, in essence, a kind of curriculum oriented to general education" (MoE, 2003b, p. 1). According to this document, the SSSCC is intended to help students in the following aspects: (1) to actively learn basic chemical knowledge and skills which are needed for their future development, have a deeper understanding about the physical world; (2) to experience the processes of scientific inquiry, learn scientific research methods, and have a deeper understanding about the nature of science; (3) to foster scientific attitudes, have a deeper understanding about the relationships among science, technology, and society (MoE, 2003b). The philosophy of the SSSCC is elaborated as follows (MoE, 2003b):

2. At the level of junior secondary schools, according to the outline of curriculum reform of basic education, the science curriculum can take either one of two forms: separated curriculum (called 'physics', 'chemistry', and 'biology', etc.) or integrated curriculum (called 'science')

1. To establish objectives of the SSSCC, which are aligned with 'knowledge and skills', 'processes and methods', 'emotions, attitudes and values' according to the needs of students as future citizens.
2. To set diversified course models in order to provide more chances for students to choose chemistry courses depending on their own interest.
3. To lead students further learn basic principles and methods of chemistry in combination with the history of the human kind in exploring substances and their changes.
4. To help students recognize the immediate relations between chemistry and human achievements, concern with social problems involved with chemistry. To cultivate students' social responsibilities and abilities of taking part in social decision-making processes.
5. To guide students experience the processes of scientific inquiry and inspire their interest in learning chemistry. To enhance students' consciousness of scientific inquiry, and facilitate the change of learning modes via chemistry experiments and other investigative activities.
6. To construct the structure of senior secondary school chemistry curriculum on the cultural background of human being. To embody the essence of the humanities in order the SSSCC to play active roles in cultivating students' spirits of humanities.
7. To advocate various evaluation strategies, including students' self-evaluation, performance evaluation. To be concerned with students' personality development, and encourage each student to approach his/her own success.
8. To provide more chances for chemistry teachers to creatively conduct their instruction and teaching research. To lead chemistry teachers to reflect in the practice of curriculum reforms so as to facilitate their professional development.

The Structure of the New SSSCC

According to the national standards of the SSSCC, the SSSCC is made up of required and selective course modules. Required course modules consist of Chemistry 1 and Chemistry 2 (Chemistry 1 precedes Chemistry 2), and 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. Each course module is designed for 36 hours and students can acquire two credits. It is required that each student should at least obtain six credits in the subject of chemistry during the period of their senior secondary schooling. That is to say, students should select at least one selective course module after they finish Chemistry 1 and Chemistry 2. This is called "4 plus 2" system according to required credits. The structure of the new SSSCC is shown in Figure 2.

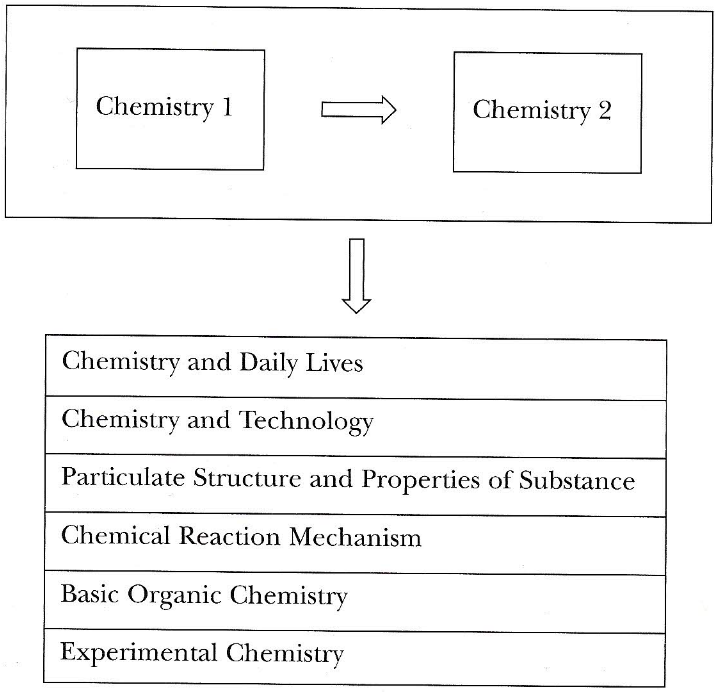

Figure 2. The structure of the new SSSCC

In the national standards of the SSSCC, the purposes of each course module are stipulated as follows.

• Chemistry 1 and Chemistry 2

To be knowledgeable about chemical substances, learn important chemical concepts, develop basic chemical conceptions and abilities of scientific inquiry, and appreciate the roles played by chemistry on social development and the interrelationship between chemistry and society.

• Chemistry and Daily Lives

To be knowledgeable about properties of common chemical substances in daily lives. To learn to investigate chemical phenomena in daily lives and appreciate the roles chemistry has played in improving the quality of human lives. To be conscious of using chemicals in a reasonable way, and be able to solve problems by use of chemical knowledge.

• Chemistry and Technology,

To be knowledgeable about the applications of chemistry in industry and agriculture. To appreciate the roles played by chemistry in the development of the national economy. To recognize the roles of chemistry in promoting technological advance.

• Particulate Structure and Properties of Substance,

To experience the processes in which scientists explored particulate structure of substance. To further learn the basic ideas about the particulate structure of substance, and to know the relationship between particulate structure of substance and its properties. To be able to explain some chemical phenomena and predict properties of substance in the view of particulate structure of substance.

• Chemical Reaction Mechanism

To know basic principles abided by chemical reactions and foster the ideas about matter change. To recognize the rules abided energy transformation in chemical reactions and appreciate the applications of chemical reaction mechanism in production, daily lives, and scientific research.

• Basic Organic Chemistry

To learn basic knowledge about components, structures, and properties of organic compounds. To learn the basic methods in organic chemistry research. To appreciate the contributions organic chemistry has made to social development.

• Experimental Chemistry

To learn basic skills and methods involved in chemical experiments via investigative activities. To further experience the processes of experimental investigations in chemistry. To recognize the important roles played by experiments in chemistry research and learning. To foster abilities of conducting chemical experiments.

In the national standards of the SSSCC, the contents of each course module are presented in the form of themes. The themes of each course module are given in Table 1. According to the designers, themes were selected from two sources. One was based on three big ideas of chemistry, 'substances', 'structures', and 'reactions', while the other was based on the relationships among science, technology, and society (personal communication with designers). For each theme, content standards are presented by several performance indicators, which are accompanied by 'recommended activities'. In these 'recommended activities', various kinds of teaching and learning methods and strategies are involved. According to the designers, these varied activities manifest the diversification of students' learning modes (Wang & Wang, 2004). The theme 'Chemistry and Health' in the course module 'Chemistry and Daily Lives' is used as an example to illustrate the presentation of the 'content standards' and the 'recommended activities' (see Table 2) .

Features of the New SSSCC: A Comparison with the Previous

In order to discern the features of the new SSSCC, I intended to compare it with previous syllabi of the SSSCC. The comparison was made on the aspects of the intentions and contents of the SSSCC, which are the main parts of the previous syllabi and the current curriculum standards. In this section, the comparison is made first in the intentions, and then in the contents of the SSSCC, though these two aspects are often interwoven.

According to Bybee and DeBoer (1994), the intentions of science curriculum can be viewed in two ways. One is focused on the knowledge, methods, and applications that are to be learned while the other is looked at the ends to which the knowledge, methods, and applications apply. In the traditional SSSCC, it used to argue that chemistry is of paramount importance to the modernization of industry, agriculture, national defense, and science and technology in China (MoE, 1978; SEdC, 1986, 1996). Therefore, the offer of chemistry in secondary schools was linked to the fulfillment of so-called socialist construction and training qualified

Table 1
Themes in required and selective course modules in the new SSSCC

Course modules	Themes
Chemistry 1	• Knowing chemistry as a science • Basics to Chemical experiments • Common inorganic elements and compounds and their applications
Chemistry 2	• Particulate structure of substance • Chemical reaction and energy • Chemistry and sustainable social development
Chemistry and Daily Lives	• Chemistry and personal health • Materials in daily lives • Chemistry and environmental protection
Chemistry and Technology	• Chemistry and exploitation and application of natural resources • Chemistry and manufacture and application of materials • Chemistry and industrial and agricultural productions
Particulate Structure and Properties of Substance	• Atomic structure and elements • Chemical bonds and properties of substances • Intermolecular forces and properties of substances • Values of investigating particulate structure of substances
Chemical Reaction Mechanism	• Chemical reaction and energy • Velocity of chemical reaction and chemical equilibrium • Ironic equilibrium in solution
Basic organic chemistry	• Components and structures of organic compounds • Properties and applications of hydrocarbon and its ramifications • Saccharide, amino acids, and protein • Synthesized polymer compounds
Experimental Chemistry	• Basics to chemical experiments • Enquiry by chemical experiments

personnel for the national development. The needs for personal, social or cultural purposes, however, were rarely mentioned. Accordingly, the basic knowledge and skills of the subject of chemistry, which were termed by Chinese scholars and practicing teachers as 'double bases' (*shuanji*), were highly valued, while practical applications were given few emphases. Furthermore, chemical applications were only used to solidify the double bases and their coverage was only limited to industrial and agricultural fields (MoE, 1978). Scientific processes had not been included as a curriculum goal until 1986 (SEdC, 1986). Training students' 'abilities' (*nengli*) had been advocated since the late 1970s but for a long time it had been confined in the four elements - observing, experimenting, thinking, and learning

Table 2
The Presentation of Content Standards and Recommended Activities in the Theme of 'Chemistry and Personal Health' in the Course Model of 'Chemistry and Daily Lives'

Content standards	Recommended activities
1. Know common organic compounds contained in foods, which are significant to personal health 2. Narrate structures and properties of amino acids, proteins, and be able to list amino acids essential in human body. 3. Understand main sources and absorbing ways of vitamin. Know the roles played by vitamin in human body. 4. Understand the important functions of microelements in human body. 5. Understand the importance of absorbing nutriment, know the relation between the nutrition balance and personal health. 6. Know some biochemical reactions occurring in the metabolism process in human body. 7. Know compositions, properties, and functions of common food additives. 8. Know main components and curative effects of some medicines.	• Discussion: The significance of edible grease to personal health. • Experimenting inquiry: the reduction of Vitamin C in fresh fruits. • Investigation or experiment: expansions in some foods. • Looking up the labels of some foods to know the nutrition components and contained additives. • Experimenting inquiry: examination of chemical components of inhibitors of acids. • Investigation: microelements in mineral water and their functions. • Looking up information and discussing: the effects of lead, iodine on personal health. • Looking up information: components, structures, and curative effects of common medicines. • Collecting information: development of the 'green foods'.

by self (Wei, 2004). Moral and political education were emphasized but mainly referred to dialectic materialism and patriotism.

As mentioned earlier, in the new SSSCC, the curriculum goals are defined by three dimensions in the view of scientific literacy: (1) knowledge and skills; (2) processes and methods; (3) emotions, attitudes, and values. In the first dimension, the components are 'basic chemistry concepts and theories', 'nature of chemical phenomena', and 'basic ideas about chemistry', 'basic knowledge and skills of chemical experiments', and 'relationship between and among chemistry and other subjects of science', etc. The components in the second dimension are 'abilities of scientific inquiry', 'consciousness of problems', 'independent thinking and cooperation with others', and 'abilities of obtaining and treating data and information'. In the third dimension, the components are 'interest in learning chemistry', 'consciousness of applying chemical knowledge', 'appreciation of the contributions of chemistry to human being and social development', 'the world view', and 'scientific attitudes and scientific spirits', etc.(MoE, 2003). Compared with the previous SSSCC, we can say that double bases are still emphasized but their meanings are expanded, at the same time, much attention are paid to personal and social aspects of chemistry in the new SSSCC. This practice reflects the intention of establishing a balance among competing goals in science education, and furthermore, provides a framework for the designers to select and organize curriculum contents for both required and selective course models.

Conventionally, chemistry curriculum contents were perceived as chemistry teaching contents in the traditional SSSCC, which were composed of six elements: basic chemistry concepts, chemical terminology, elements and compounds, fundamental chemistry theories, chemistry experiments, and chemistry calculations. While analyzing the 1978 secondary school chemistry curriculum, Liu (1983) described the different roles played by these six elements in this curriculum: "chemistry experiment is the basis, chemistry theories are the main thread, elements and compounds are the skeleton, chemistry calculation is the application and development of other five, chemical terminology and basic concepts are the thinking tools in learning and understanding various chemical problems " (p.26). This description was prevalent among chemistry teachers in schools and chemistry educators in universities. In the previous SSSCC, chemical applications were involved indeed, in most cases, however, they were marginalized by subject knowledge. In the 1996 senior secondary school chemistry syllabus, for instance, some knowledge points about chemical applications, such as, 'iodine and personal health', 'metallic recycle and environmental protection', 'new types of polymer materials' were given lowest requirements - 'tentatively knowing' or suggested as 'optional studies' (SEdC, 1996). It is obvious that chemistry curriculum contents were dominated by chemistry subject knowledge with few emphases given to chemical applications in the traditional SSSCC. In the new SSSCC, this situation has changed. Of the 25 themes in both required and the selective course models in the national standards of the SSSCC, there are seven themes that are closely relevant to chemistry applications, nearly accounting for one to third of all the themes. These themes are: 'Chemistry and sustainable social development', 'Chemistry and human health', 'Materials in daily lives', 'Chemistry and environmental protection', 'Chemistry and exploitation and applications of natural resources', 'Chemistry and manufacture and applications of materials', and 'Chemistry and industrial and agricultural production' (see Table 1).

Discussion

Standards-based reforms seemed to have been prevalent in science curriculum reform across the world in recent years. The most influential documents are *National Science Education Standards* (NRC, 1996), *Project 2061: Science for All Americans* (AAAS, 1989) and *Benchmarks for Science Literacy* (AAAS, 1993) in the United States, and *Science in the National Curriculum* (Department for Education, 1995) in the United Kingdom. In these documents, the vision of scientific literacy guides the reform efforts in defining and specifying what K-12 students should know and be able to do in science. According to the National Council of Teachers of Mathematics (NCTM, 1989, cited in Raizen, 1998), standards serve as three purposes: minimal criteria for quality; an expression of expectations of goals; and means for leading a group toward new goals. In the case of the new SSSCC in China, the national standards of the SSSCC seem to include all of these three purposes. However, the document of national standards of the SSSCC, in its nature, is a subject curriculum, therefore, it should be closer to the practical teaching than those mentioned above, and therefore it has to deal with these specific curriculum issues, such as the order, structure, and organization of curriculum contents. More often these issues are not involved in those education standards in science like

National Science Education Standards (Bybee, *et al*, 1997). In this sense, the approaches to and strategies of dealing with these issues in the new SSSCC could be helpful for stakeholders who intend to transform the purpose of achieving scientific literacy in practice.

In particular, the experiences of the new SSSCC could be significant in handling the tension between two curriculum orientations in science – science for more able students who will continue to learn sciences in their further studies and science for the majority of students who will become future citizens. As we know, this tension almost exists in all stages of basic education (K-12) but it seems to be more evident in upper secondary schooling. As we see in the section of the structure of the new SSSCC, various themes in both required and selective course models in the new SSSCC are socially and technologically relevant. This practice can be used to cater for the needs of those students, who will not further study chemistry or related fields in their tertiary education, or go to job markets after their graduation from senior secondary schools. In fact, the needs for the more able students has never been neglected in this curriculum. This is mainly reflected in the selection of the themes of Chemistry 1 and Chemistry 2, which are mainly based on the conceptual structure of chemistry as a science. Furthermore, it is obvious that some selective course modules, such as 'Particulate Structure and Properties of Substance', 'Chemical Reaction Mechanism', 'Basic Organic Chemistry', and 'Experimental Chemistry', can meet the needs of the more able students who could continue studying chemistry in the future.

As part of curriculum reform in China, the new SSSCC can be seen as a solution proposed by curriculum designers to the problems identified in practice in chemistry teaching. From the brief account of the process of generating the new SSSCC, we can see that this is a typical Tyler's rational linear approach to producing the curriculum (Marsh & Willis, 2003). The constructs of what to be taught and learned reflect the voices of chemistry educators and academic chemists in universities rather than those of practicing chemistry teachers. Furthermore, the ideas, objective, contents, and terms are mainly ideas originated in western countries. Compared with the previous syllabi, tremendous change has occurred in the forms and contents of the national standards of the SSSCC, the intermediate curriculum between the national teaching program and textbooks (Wu, *et al*, 1992). Moreover, it seems that there are technical problems in presenting the ideas and contents in the new SSSCC. For example, the requirements of content standards under the various themes are vaguely expressed. Such a treatment can potentially make practicing teachers, textbooks editors, examination board face difficulties in dealing with the relation between the national standards and their own concerns. Combining these problems existing in the process and the forms of the national standards of SSSCC, I cannot help but doubt whether this official document will be implemented effectively in practice. Fortunately, supported by the central government, various measures have been taken to strengthen pre-and in-service teacher education, and the reform of the system and strategies of the university entrance examination, which has always played the role of 'conductor's baton' (*zhihui bang*) in secondary school teaching in China, is ongoing. All of these efforts reflect the systemic nature of contemporary curriculum reform, and in the case of chemistry curriculum, might be helpful to propel the full implementation of the national standards of the SSSCC.

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