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ARTICLE

Examining the Changes in Representations of Nature of Science in Chinese Senior High School Chemistry Textbooks

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Abstract
This paper aimed to examine the changes in the representations of nature of science (NOS) in Chinese senior high school chemistry textbooks under the influence of the new curriculum ideas. The study was conducted based on an analytical framework in which the aspects of NOS, the approaches to address NOS, and the content relation of NOS aspects were involved. Two series of the new and old chemistry textbooks of required course modules were selected as analysis targets. The results revealed that chemistry textbooks paid more attention to classical views of NOS than contemporary views of NOS. The aspects of NOS were unevenly presented in different chapters of textbooks. The new textbooks covered the NOS aspects more comprehensively and frequently than the old ones. Regarding the approaches, the implicit approach was dominant. Compared with old ones, the proportions of the explicit-reflective and historical-explicit-reflective approaches have increased in new textbooks, but were still not high. Lastly, the content relation of NOS aspects were more of content-embedded than content-generic both in new and in old textbooks. At the end of this paper, the implications of the findings and the suggestions for the further studies were discussed.

1 Introduction

Understanding the nature of science (NOS) is one of the vital components of citizens' scientific literacy, and assisting students in developing an appropriate view of NOS is one of the most common educational goals of science curriculum (Lederman & Lederman, 2014). From a curriculum point of view, NOS can be viewed as extensions of what should be taught in school science, in the sense that it endeavors to transcend the traditional

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content-oriented science curriculum that often fails to capture and to teach authentic scientific practices (Park et al., 2020). Based on the "Family Resemblance Approach" (FRA) as developed by Erduran and Dagher (2014), NOS is characterized as a cognitive-epistemic and social-institutional system. In this system, the cognitive, epistemic, and social-institutional components of science coexist and interact (Kaya et al., 2019). These components contribute to make science "science" and explain how science works at different levels from the mind to the social institutions (Erduran et al., 2020). Although scientists have undergone a long-running debate over "what science is on earth," they reached a consensus that certain aspects of NOS should be taught to children of appropriate ages. This helps students better comprehend the scientific enterprise and strengthen the ability to make scientific decisions, which is of great significance for them to establish a correct view of nature and science, and to cultivate a spirit of skepticism, criticism, and free exploration (Abd-El-Khalick et al., 1998).

As we know, NOS is viewed as embodying a set of aims and values, practices, methodologies, and social norms that are worthy of inclusion in the science curriculum (Erduran et al., 2019). In recent years, NOS has been presented as the main theme in science education reform documents promulgated by many developed countries, for example, *Next generation science standards* (NGSS Lead States, 2013) in the USA and *National curriculum in England: science programmes of study* (DFE, 2015) in Great Britain. The National Science Teachers Association (NSTA, 2020) also proposed that all those who are involved in science teaching and learning should have a common view of the NOS. Influenced by the ideological trend of educational reform in western countries, Chinese science education has gradually begun to emphasize the value of NOS. In the recently issued *Chemistry Curriculum Standards of Senior High School (the 2017 version)* (MOE, 2018), there are 5 explicit references to NOS, designed to promote students' understanding of NOS. Among these 5 references, in the section of suggestions on textbook compilation, it is especially put forward that chemistry textbooks should "utilize excellent cases in the development of science and technology to guide students to be familiar with NOS, realize the characteristics of scientific enterprise, consciously inherit scientific culture, and promote the spirit of science" (MOE, 2018), which was never proposed in the previous national chemistry curriculum standards.

Generally speaking, as the critical medium for science teaching, textbooks are not only the direct embodiment of curriculum standards, but also provide materials and guidance for teachers to teach NOS, which are important sources for the development of teachers and students' view of NOS (Abd-El-Khalick et al., 2008). As a result, the representations of NOS in science textbooks have received a great amount of attention, as they play a critical role in guiding instruction and learning (Wei et al., 2013; Brunner & Abd-El-Khalick, 2020; McComas, 2017; McDonald, 2017). In the circle of chemistry education in China, the teaching and learning of chemistry has always been centered on textbooks. Specifically, chemistry textbooks are regarded as the substantiation of the curriculum, and the ideas of the new curriculum should be delivered to teachers and students through them (Wang, 2010). However, little research has been performed to analyze the representations of NOS in Chinese chemistry textbooks. Meanwhile, as mentioned above, the NOS has been included explicitly in the new chemistry curriculum standards, especially in the section of suggestions on textbook compilation (MOE, 2018). Therefore, it is necessary to analyze the textbooks based on the latest curriculum standards (called new textbooks) and compare them with the those based on the previous curriculum standards (called old textbooks), in order to examine the changes in the representations of NOS in Chinese senior high school chemistry textbooks under the influence of the new curriculum ideas. This

study can inform chemistry educators and textbook authors of the representations of NOS aspects in chemistry textbooks and how the representations may be improved in future revisions to better align with the new curriculum standards and consensuses on how NOS should be represented.

2 Literature Review

In this section, we reviewed literature about studies of NOS from the following three respects, namely aspects of NOS, approaches for teaching NOS, and researches on NOS integrated in science textbooks.

2.1 Aspects of NOS

In the process of studying the NOS, a great many scholars have provided definitions of it but with some disputes (McComas, 1998). Fortunately, the science education community has gradually reached a consensus that in order to spare teachers and students from over-complicated philosophical debates, the question of "what is the NOS" needs to be properly avoided, and the issue of "which aspects of NOS should be acquired" needs to be discussed.

On the aspects of NOS, different scholars and different countries' science education documents have different expressions, among which, seven aspects proposed by Lederman et al. (2002) are representatives. They believe these aspects are accessible to K–12 students and relevant to their daily lives, namely, (1) the empirical nature of scientific knowledge, (2) scientific theories and laws, (3) the creative and imaginative nature of scientific knowledge, (4) the theory-laden nature of scientific knowledge, (5) the social and cultural embeddedness of scientific knowledge, (6) myth of the scientific method, and (7) the tentative nature of scientific knowledge. These aspects are commonly referred to as the "consensus view" of NOS (Erduran et al., 2019). After that, alternative perspectives on NOS have emerged including whole science (Allchin, 2011), features of science (Matthews, 2012), and the FRA (Dagher & Erduran, 2016; Erduran & Dagher, 2014). For instance, FRA presents NOS as a cognitive-epistemic and social-institutional system with a set of categories: aims and values, scientific methods, scientific practices, scientific knowledge, and social-institutional aspects of science (Erduran & Dagher, 2014). Recently, the document of NSTA (2020) clearly articulated the aspects of NOS, which are critical and developmentally appropriate for precollege students, including tentative nature of scientific knowledge, scientific method, observation and inference, creativity and imagination in science, empirical evidence of science, subjectivity in science, theories and laws, and socio-cultural context of science. The document pointed out that if amply reflected in science curricula and textbooks, and taught to students in the early stages of science education, these aspects can help students develop an interest in science, and gain a better understanding of scientists and their researches. In addition to the above aspects of NOS, Aydin et al. (2013) conducted a content analysis to examine 65 papers published in *The Science Teacher*, and found that "human endeavor" was the most cited aspect of NOS. Besides, some other aspects, including science as a solitary pursuit (Irez, 2009), interdisciplinary nature of science (NGSS Lead States, 2013), use of models (Vesterinen et al., 2013), inferential/theoretical (Aydin &

Tortumlu, 2015), and science and technology (Upahi et al., 2020) also gradually appeared in relevant literature over time.

It can be seen from the above discussions that the NOS has incorporated a great deal of aspects. According to Wan et al. (2018), these aspects could be generally classified into two categories, i.e., classical and contemporary views of NOS, which refer respectively to the classical view of positivism and the contemporary view of relativism. The former emphasized the classical NOS (e.g., objective observation, classification, evidence, experimental thinking) that embodies the spirit of rationality, making people get rid of myths and superstitions and advocate rationality, which is the cognitive basis of contemporary views of NOS; the latter emphasized the NOS of scientific reflection (e.g., relativity in science, subjectivity in science, the limitations of science).

At last, in this study, 12 aspects of NOS were selected for analyzing chemistry textbooks (Table 1), among which 6 aspects were from NSTA (2020) document and the other 6 aspects were from related literature, including human endeavor (Aydin et al., 2013), science as a solitary pursuit (Irez, 2009), interdisciplinary nature of science (NGSS Lead States, 2013), use of models (Vesterinen et al., 2013), inferential/theoretical (Aydin & Tortumlu, 2015), and science and technology (Upahi et al., 2020). Collectively, these aspects have been consistently researched and reported in science education journals (e.g. Abd-El-Khalick et al., 2017; Aydin & Tortumlu, 2015; Lederman et al., 2013).

2.2 Approaches for Teaching NOS

In teaching aspects of NOS, there are three different approaches, namely, explicit-reflective, implicit, and historical approaches (Abd-El-Khalick & Lederman, 2000). The explicit-reflective approach assumes that students learn about NOS by participating in activities through which they design, collect data, analyze and interpret, and communicate findings with peers. After the activity, teachers explicitly discuss NOS aspects included in the activity through the participation of students. In contrast, the implicit approach assumes that students learn about NOS when they participate in inquiry activities. In other words, an explicit discussion on the aspects of NOS is not employed in the implicit approach. Lastly, the historical approach addresses NOS by the use of cases which happened in the history of science, stories of scientific inventions, and discoveries that happened by coincidence. While each of these approaches has its own value, it has been revealed by researches that the explicit-reflective approach to teaching aspects of NOS results in a better understanding of NOS than the implicit one (Khishfe, 2022; Khishfe & Abd-El-Khalick, 2002).

Table 1 Aspects of NOS in this study

Aspects from NSTA document	Other aspects from related literature
Tentative nature of scientific knowledge	Human endeavor
Scientific method	Science as a solitary pursuit
Creativity and imagination in science	Interdisciplinary nature of science
Empirical evidence of science	Use of models
Subjectivity in science	Inferential/theoretical
Theories and laws	Science and technology

2.3 Research on NOS Integrated in Science Textbooks

There has been a long history over the researches regarding the representations of NOS in textbooks. In earlier studies, researchers mainly analyzed the proportion of NOS in textbooks. For example, Chiappetta et al. (1991) investigated the presentation of NOS in five different types of science textbooks and found these textbooks stressed scientific knowledge but neglected scientific epistemology. Chiappetta and Fillman (2007) examined five high school biology textbooks to determine their inclusion of NOS, and revealed that the new editions covered more NOS contents than the previous editions 15 years ago.

After that, the approaches to address NOS started to be involved in the researches. For instance, Abd-El-Khalick et al. (2008) analyzed 14 American chemistry textbooks, including five series spanning 10–40 years. In this study, the textbooks were graded on each of the target NOS aspects (e.g., empirical, inferential, creative), reflecting the accuracy, completeness, and manner (explicit versus implicit) in which these aspects were addressed. Results indicated that NOS was poorly represented in the textbooks and there has been no obvious development and progress in the past 40 years. In another study, Zhuang et al. (2021) evaluated the characteristics of NOS in five versions of Chinese high school physics textbooks, and found that the representations of NOS in all five textbooks were far from satisfactory and more than half of the NOS aspects were represented implicitly.

In recent studies, apart from the distribution of NOS and the approaches used, researchers also focused on the content relation of NOS aspects. Representatives are the studies of Aydin and Tortumlu (2015) and Upahi et al. (2020). Aydin and Tortumlu (2015) examined the new and old Turkish high school chemistry textbooks and revealed that the frequency of NOS aspects stated in the textbooks was reduced from grades 9–12, the implicit approach was used more, and the content relation of NOS aspects was quite different between the new and old textbooks. The researchers concluded that some positive changes have taken place in Turkish high school chemistry textbooks in terms of the representations of NOS. Similarly, Upahi et al. (2020) analyzed three Nigerian chemistry textbooks based on the analytical framework of the aspects of NOS, approaches used, and the content relation of NOS. The results showed that there was discrepancy in the proportions of different aspects of NOS in the textbooks. The findings further revealed that the implicit approach was dominant, and the content relation of NOS aspects was more embedded in two-thirds of textbooks.

It is indicated that researches on NOS integrated in science textbooks were often carried out based on the analytical framework for the distribution of NOS aspects, the approaches used, and the content relation of NOS aspects. Therefore, we analyzed Chinese senior high school textbooks from the aforementioned three dimensions, in order to study NOS more comprehensively.

3 Research Questions

The present study aimed to examine the changes in the representations of NOS in Chinese senior high school chemistry textbooks, and attempted to provide answers to the following research question:

What are the differences between the old and new textbooks in terms of (1) the distribution and frequency of NOS aspects, (2) the approaches to address NOS, and (3) the content relation of NOS aspects?

4 Research Method

Content analysis was employed in this study as the research methodology to examine the representations of NOS in chemistry textbooks. According to Stemler (2001), content analysis aims to discover and describe the phenomena under consideration by compressing large volumes of words into fewer content categories based on explicit rules of coding. In essence, content analysis can be qualitative and quantitative (Berg & Lune, 2017). To provide empirical evidence for the research questions, both of these two genres were adopted in this study. In this section, research method was clarified from the following three respects, namely data sources, the analytical framework, and data analysis.

4.1 Data Sources

Chinese senior high school chemistry curriculum comprises required and selective course modules (Wei, 2019). Textbooks of required course modules are selected as analysis targets in this study, which are required for all senior high school students, completed in grade 10. In the stage of basic education in China, for a given subject, there are several series of textbooks produced by various publishers under the national curriculum standards (Wei, 2012). Given the fact that senior high school chemistry textbooks published by People Education Press (PEP) and Shandong Science and Technology Press (SSTP) are widely used and representative in China, we targeted chemistry textbooks published by PEP and SSTP in this study. Since two textbooks were compiled for the required course modules before and after the curriculum reform respectively, there are 8 targeted textbooks in total for this study. The basic information of these textbooks is listed in Table 2, among which, the first four are new textbooks and the last four are old textbooks.

The compilation of the new textbooks is guided by the latest curriculum standards (MOE, 2018), which set out the required courses contain five topics: (1) chemical science and experimental inquiry, (2) common inorganic substances and their applications, (3) the structures of substances and chemical reactions, (4) simple organic compounds and their applications, and (5) chemistry and social development. The compilation of the

Table 2 The basic information of these eight textbooks

	Book title	Editor-in-chief	Publishing year
New textbooks published by PEP	Chemistry Volume I	Wang and Bi	2019
	Chemistry Volume II	Wang and Bi	2019
New textbooks published by SSTP	Chemistry Volume I	Wang	2019
	Chemistry Volume II	Wang	2019
Old textbooks published by PEP	Chemistry 1	Song	2007
	Chemistry 2	Song	2007
Old textbooks published by SSTP	Chemistry 1	Wang	2007
	Chemistry 2	Wang	2007

old textbooks is based on the previous curriculum standards (MoE, 2003), which set out the required courses contain six topics: (1) understanding chemical science, (2) basics of chemical experiments, (3) common inorganic substances and their applications, (4) the structures of substances, (5) chemical reactions and energy, (6) chemistry and sustainable development. According to the topics set in the curriculum standards, the chapter arrangement of the new and old textbooks in required course is shown in Table 3.

Although the order and names of chapters are somewhat different, a closer look shows that the main contents of the new and old textbooks are basically the same. Besides, the layout and structure of the new and old textbooks are similar. Chapters and sections constitute the main body of the textbooks. Each chapter has two to four sections, which are the basic teaching units in class. In most cases, some special columns, such as "experiments," "inquiry activities," "thinking and discussion," and "chemistry and technology" are inserted in the texts. The new textbooks has more columns than the old ones (e.g., method guide). Main knowledge points are summed in the "summary of this chapter." The chapters end with student exercises. The similarities in contents and structure between the new and old textbooks provide a basis for their comparison. It should be noted that although the required course modules contain two textbooks, we compare the differences between the old and new textbooks in the whole required course module. Thus, for a certain version, we treat two books as one source unit in the process of analysis.

4.2 Analytical Framework

As mentioned earlier, the analytical framework of this study mainly included three dimensions, namely, (1) the aspects of NOS, (2) the approaches to address NOS aspects, and (3) the content relation of NOS aspects. There are 12 aspects of NOS, whose specific meanings are shown in Table 4.

In the dimension of the approaches to address NOS aspects, due to the fact that the lack of activities for teaching NOS aspects in Chinese chemistry textbooks, we had to refer to the literature of Aydin and Tortumlu (2015) to modify the original meanings of explicit-reflective and implicit approaches (Abd-el-Khalick & Lederman, 2000). In this study, the explicit-reflective approach means that the textbook authors explicitly mentioned the NOS aspect as well as provided explanations and examples for addressing that aspect, whereas the implicit approach means that the NOS aspect was mentioned implicitly without stating the NOS aspect clearly and explicitly. Based on the modifications of the above meanings, the historical approach and the explicit-reflective and implicit approaches form hybrid approaches, that is, the historical-explicit-reflective and historical-implicit approaches. Hence, there are 4 approaches to integrate NOS aspects in the textbooks in this study, namely, explicit-reflective, implicit, historical-explicit-reflective, and historical-implicit approaches, whose specific explanations are shown in Table 5.

The content relation of NOS aspects is divided into two ways: content-embedded and content-generic (Aydin & Tortumlu, 2015; Lederman, 2007). The former involves integrating NOS aspects into the content taught. For instance, when presenting the structure of benzene, the history of Kekule's discovery of the benzene ring is introduced, and creativity and imagination in science aspects of NOS are underlined, which reflects the integration of NOS aspects into the subject content. The content-generic way involves addressing NOS aspects without using the content taught. For example, the "old or young lady" picture is made use of to illustrate the subjectivity in science aspect of NOS.

Table 3 The chapter arrangement of the new and old textbooks in required course

		Chapter 1	Chapter 2	Chapter 3	Chapter 4
New textbooks-PEP	Chemistry Volume I	Substances and their changes	Vital elements in seawater—sodium and chlorine	Iron and metal material	Structures of substances and the periodic law of elements
	Chemistry Volume II	Vital non-metallic elements in chemical production	Chemical reactions and energy	Organic compounds	Chemistry and sustainable development
New textbooks-SSTP	Chemistry Volume I	Learn about chemical science	Elements and the material world	Properties and transformations of substances	
	Chemistry Volume II	Atomic structure and the periodic law of elements	Chemical bond and the law of chemical reaction	Simple organic compounds	
Old textbooks-PEP	Chemistry 1	Learn about chemistry from experiments	Chemical substances and their changes	Metals and their compounds	Nonmetals and their compounds
	Chemistry 2	Structures of substances and the periodic law of elements	Chemical reactions and energy	Organic compounds	Chemistry and development and utilization of natural resources
Old textbooks-SSTP	Chemistry 1	Learn about chemical science	Elements and the material world	Elements in nature	Elements in the material family
	Chemistry 2	Atomic structure and the periodic law of elements	Chemical bond and chemical reactions and energy	Vital organic compounds	

Table 4 Detailed explanations of the aspects of NOS

Aspects of NOS	Explanation
Tentative nature of scientific knowledge	Scientific knowledge is reliable, but it may be changed or modified in light of new evidence or re-interpretation of original evidence
Scientific method	There is no fixed, single, step-by-step scientific method employed by scientists to conduct researches
Creativity and imagination in science	The creativity and imagination of scientists are vital ingredients in every step of scientific inquiry (e.g., Augustus Kekule's imagination of the benzene ring)
Empirical evidence of science	Scientific knowledge is acquired and accumulated through data collections, observations, experiments, etc. Scientists support their claims and explanations with the data collected
Subjectivity in science	The questions asked, observations made and conclusions reached in science are to some extent subjected to the experiences and sociocultural backgrounds of scientists
Theories and laws	Scientific laws are explored to describe various phenomena observed and theories are explored to explain them. Although laws are related to theories, they are different concepts and cannot be converted into each other
Human endeavor	When scientists conduct research, they share their research with the public. During this process, peers review their research. Different scientists are involved in this process
Science as a solitary pursuit	Collaborative efforts from multiple scientists are required to conduct scientific researches
Interdisciplinary nature of science	There are no clear-cut compartments of science. Fields are related to each other
Use of models	Models are used in science to make understanding and interpretation easier. Models do not represent the real structure
Inferential/theoretical	Developments in science occur owing to the data collected through observations and experiments. Additionally, interpretations of the theoretical knowledge and the inferences made are sources of these developments
Science and technology	Science and technology are different fields. Science aims at understanding the nature whereas technology focuses on application and making life easier

Table 5 Approaches to address NOS aspects and their explanations

Approaches	Explanation
Explicit-reflective	The authors clearly state the NOS aspects in the textbooks, and provide relevant explanations and appropriate examples, but do not involve the history of science
Implicit	The authors do not clearly and explicitly reflect the NOS aspects in the textbooks, nor involve the history of science. Students need to understand the NOS aspects indirectly through the descriptions in the textbooks
Historical-explicit-reflective	The textbook authors explicitly state and explain the NOS aspects by using the histories of science
Historical-implicit	The textbook authors implicitly reflect the NOS aspects by using the cases that occurred in the history of science

4.3 Data Analysis

This study was conducted by means of a page-by-page analysis. Referring to the research of Upahi et al. (2020), each paragraph in the texts and special columns was taken and coded as a unit of analysis. Since the student exercises in the textbooks are aimed at improving students' ability to transfer and apply knowledge and their ability to analyze and solve problems, which almost do not involve the aspects of NOS, the student exercises are not within the analysis scope of this study. The number of paragraphs analyzed for each version of the textbooks is 862 (new textbooks-PEP), 1070 (new textbooks-SSTP), 742 (old textbooks-PEP), and 984 (old textbooks-SSTP). It should be noted that when two or more aspects of NOS were involved in the same unit of analysis, each of these aspects would be counted once; if no aspect of NOS was involved in a unit of analysis, it would not be counted.

According to three dimensions of the analytical framework, this study kept to the following operational procedure and coding approach to identify its attributes and count them. Firstly, the coder read a certain paragraph entirely, judged which aspects of NOS involved in it, selected the relevant sentences, and marked the corresponding aspect of NOS; secondly, according to whether the aspect of NOS is clearly stated or combined with relevant historical cases, the coder determined the approach to address the NOS aspect; finally, according to whether the NOS aspect is integrated into the content taught, the coder determined the content relation of the NOS aspect. All paragraphs (a total of 3658) were analyzed in accordance with the above procedure, and the analysis results were recorded in the table. Table 6 shows some analysis examples of the new textbooks published by SSTP, which would provide readers with details of the procedure for coding content text for NOS aspects, approaches used, and content relation of the NOS aspects.

Having analyzed and coded all paragraphs, it is necessary to perform quantitative statistics on the data to figure out the overall representation of NOS in each version of textbooks. Firstly, the frequency of each NOS aspect should be counted and then divided by that of total NOS aspects, in order to obtain the percentage of each NOS aspect. Secondly, in a similar way, the frequencies and percentages of the four approaches to address NOS as well as the two ways of the content relation of NOS aspects should be counted.

To establish the trustworthiness of the texts analyzed, the investigator triangulation was used (Patton, 2002). Specifically, independent coding was conducted by the first three authors to reduce the subjectivity. The average mutual agreement between the three coders reached 86%, indicating that that the coding consistency was high and the data was reliable (Miles & Huberman, 1994). For different or controversial opinions, discussions were held to reach a consensus. For instance, in texts about Rutherford in Table 6, coder 1 and coder 3 believe that the text mainly describes Rutherford's scientific research through experiments and data calculations, involving "empirical evidence of science," while coder 2 assumes that, in addition to empirical evidence, the text also introduces the nuclear atomic model and should be coded as "use of models." During the discussion, coder 1 and coder 3, combined with the meaning of "use of models," point out to coder 2 that although the text introduces the nuclear atomic model, it does not explicitly or implicitly convey the value and essence of models to readers, so this text should not be coded as "use of models." Coder 2 was finally persuaded by coder 1 and coder 3, and they reached a consensus that the text should be only coded as "empirical evidence of science." It should be noted that all of those chemistry textbooks analyzed in this study are in Chinese and the coding was done in Chinese. To present this article, the four examples in Table 6 were subsequently

Table 6 The analysis examples of the new textbooks published by SSTP

Excerpts from the textbooks	Aspects of NOS	Approaches	Content relation
"The establishment of chemical theory and the revelation of chemical laws both play an extremely vital role in the development of chemical science. Please choose one of the above theories or laws and discuss its contribution to the development of chemical science and its effect on people's understanding of substances and their changes." (Wang, 2019a, p.3)	Theories and laws	Explicit-reflective	Content-generic
"For example, chemical science promoted the development of ecology. Chemical ecology, which aims at studying the chemical relationships and mechanisms between organisms, was born in the 1950s, providing scientific models and theoretical basis for the study of pest management, biodiversity protection, and rational utilization of biological resources." (Wang, 2019a, p.4)	Interdisciplinay nature of science	Implicit	Content-generic
"Rutherford, a British physicist, proposed the nuclear atomic model after theoretical analysis and calculation based on the alpha particle scattering experiment: an atom is made up of a nucleus, a positively charged nucleus at the center of the atom, and electrons outside the nucleus; electrons have negative charges and travel at high speed in space around the nucleus." (Wang, 2019b, p.2)	Empirical evidence of science	Historical-explicit-reflective	Content-embedded
"On the basis of critically inheriting predecessors' work, Mendeleev revised, analyzed and generalized a large number of experimental facts, and summarized the periodic law of elements." (Wang, 2019b, p.19)	Science as a solitary pursuit	Historical-implicit	Content-embedded

translated into English, and an English expert was invited to check the correctness of the translation.

5 Results

In this section, we presented the results from three dimensions: the aspects of NOS, the approaches to address NOS, and the content relation of NOS aspects.

5.1 The Distribution of NOS Aspects in Textbooks

The distribution of various NOS aspects in textbooks is presented in Table 7. On the whole, compared to old ones, two series of new textbooks incorporated all 12 aspects of NOS, addressing NOS more comprehensively. NOS aspects had the most counts (up to 160 in total) in the new textbooks published by SSTP, but the least (only 72 in total) in old ones published by PEP; the frequency of NOS aspects stated in new textbooks has increased significantly compared to the old ones from the same publisher. Regarding the distribution of NOS aspects, a similar tendency was observed in the four versions of textbooks. The proportions of empirical evidence of science and science and technology were among the top in each version, whereas the proportions of creativity and imagination in science, subjectivity in science, theories and laws, science as a solitary pursuit, and use of models were

Table 7 The distribution of various NOS aspects in chemistry textbooks

Aspects of NOS	New textbooks-PEP (Chemistry Volume I and Chemistry Volume II)		New textbooks-SSTP (Chemistry Volume I and Chemistry Volume II)		Old textbooks-PEP (Chemistry 1 and Chemistry 2)		Old textbooks-SSTP (Chemistry 1 and Chemistry 2)	
	N	*P*(%)	*N*	*P*(%)	*N*	*P*(%)	*N*	*P*(%)
Tentative nature of scientific knowledge	14	15.73	16	10.00	8	11.11	12	9.45
Scientific method	1	1.12	8	5.00	0	0.00	2	1.57
Creativity and imagination in science	1	1.12	5	3.12	2	2.78	2	1.57
Empirical evidence of science	16	17.98	32	20.00	29	40.28	24	18.90
Subjectivity in science	2	2.25	3	1.88	1	1.39	0	0.00
Theories and laws	1	1.12	2	1.25	2	2.78	2	1.57
Human endeavor	5	5.62	13	8.13	3	4.17	6	4.73
Science as a solitary pursuit	2	2.25	5	3.12	0	0.00	3	2.36
Interdisciplinary nature of science	13	14.61	12	7.50	4	5.55	18	14.18
Use of models	3	3.37	4	2.50	1	1.39	5	3.94
Inferential/theoretical	13	14.61	24	15.00	6	8.33	11	8.66
Science and technology	18	20.22	36	22.50	16	22.22	42	33.07
Total number of aspects	12		12		10		11	
Total count	89	100	160	100	72	100	127	100

The number in the table refers to the count of a certain aspect of NOS involved in textbook paragraphs. The percentage in the table is the count of a certain aspect of NOS divided by the total count

very low (less than 5%) in each version, which indicates that the representations of these aspects were not improved conspicuously in new textbooks and required to be stressed and strengthened.

More specifically, the number and frequency of NOS aspects involved in each chapter of the four versions of textbooks are shown in Table 8, from which it can be seen that NOS is unevenly presented in different chapters. More NOS is addressed in some chapters or topics (e.g., learn about chemical science, the periodic law of elements, and the properties and applications of inorganic substances); conversely, less NOS is addressed in some other chapters or topics (e.g., chemical reactions and energy, organic compounds), which exists and continues in both old and new textbooks.

5.2 The Approaches to Address NOS Aspects in Textbooks

The distribution of the approaches to address NOS aspects in textbooks is presented in Table 9. As Table 9 shows, with respect to the distribution of the approaches used, a common tendency was observed in different versions of textbooks. In all versions, except for new textbooks published by SSTP, the most cited approach was the implicit one, followed by the historical-implicit one, again the explicit-reflective one, and finally the historical-explicit-reflective one. What can be deducted from the table is that the percentage of the implicit approach was higher than that of the explicit one, regardless of whether textbooks addressed NOS with or without historical cases. In addition, the percentages of the explicit-reflective and historical-explicit-reflective approaches have increased in new textbooks, compared to old ones which less addressed NOS explicitly.

5.3 The Content Relation of NOS Aspects in Textbooks

The analysis of the content relation of NOS aspects is presented in Table 10. It can be seen from the statistical results that no matter which version, the content relation of NOS aspects was dominated by the content-embedded, accounting for more than 80%. Compared to old ones, the frequency and proportion of the content-generic have increased in new textbooks, which was largely attributed to the method guide columns. They were designed to directly present the general methods, which are commonly used in the process of scientific research and chemistry learning, and involved the NOS aspects (e.g., models and predictions). Additionally, the new textbooks published by SSTP laid emphasis on the methods and procedures of studying the properties of substances, and separated them into independent sections, where the contents relevant to NOS (e.g., the specific definitions of observations, hypotheses, inferences, and their roles in the process of scientific research) were specially conveyed and specifically explained through the combination with the experiments in the following paragraphs.

6 Discussions

In this study, we have comprehensively examined the changes in the representations of NOS in Chinese senior high school chemistry textbooks under the influence of the new curriculum ideas. Particularly, the analysis was based on the analytical framework for the distribution of NOS aspects, the approaches used, and the content relation of NOS

Table 8 Number and frequency of NOS aspects involved in each chapter of textbooks

		Chapter 1	Chapter 2	Chapter 3	Chapter 4
New textbooks-PEP	Chemistry Volume I	Substances and their changes (4, 9)	Vital elements in seawater-sodium and chlorine (7, 11)	Iron and metal material (4, 10)	Structures of substances and the periodic law of elements (8, 27)
	Chemistry Volume II	Vital non-metallic elements in chemical production (9, 10)	Chemical reactions and energy (4, 10)	Organic compounds (3, 3)	Chemistry and sustainable development (3, 9)
New textbooks-SSTP	Chemistry Volume I	Learn about chemical science (12, 33)	Elements and the material world (5, 29)	Properties and transformations of substances (8, 36)	
	Chemistry Volume II	Atomic structure and the periodic law of elements (12, 35)	Chemical bond and the law of chemical reaction (5, 12)	Simple organic compounds (7, 15)	
Old textbooks-PEP	Chemistry 1	Learn about chemistry from experiments (4, 5)	Chemical substances and their changes (2, 4)	Metals and their compounds (2, 10)	Nonmetals and their compounds (6, 24)
	Chemistry 2	Structures of substances and the periodic law of elements (5, 13)	Chemical reactions and energy (4, 5)	Organic compounds (5, 6)	Chemistry and development and utilization of natural resources (3, 5)
Old textbooks- SSTP	Chemistry 1	Learn about chemical science (11, 28)	Elements and the material world (4, 12)	Elements in nature (9, 28)	Elements in the material family (2, 25)
	Chemistry 2	Atomic structure and the periodic law of elements (6, 22)	Chemical bond and chemical reactions and energy (3, 3)	Vital organic Compounds (6, 9)	

The first number in parentheses is the number of NOS aspects involved in each chapter; the second number in parentheses is the frequency of NOS aspects involved in each chapter

Table 9 The distribution of the approaches to address NOS aspects in chemistry textbooks

Approaches	New textbooks-PEP (Chemistry Volume I and Chemistry Volume II)		New textbooks-SSTP (Chemistry Volume I and Chemistry Volume II)		Old textbooks-PEP (Chemistry 1 and Chemistry 2)		Old textbooks-SSTP (Chemistry 1 and Chemistry 2)	
	N	*P*(%)	*N*	*P*(%)	*N*	*P*(%)	*N*	*P*(%)
Explicit-reflective	8	8.99	31	19.37	6	8.33	13	10.24
Implicit	54	60.67	96	60.00	55	76.39	58	45.67
Historical-explicit-reflective	5	5.62	9	5.63	1	1.39	1	0.79
Historical-implicit	22	24.72	24	15.00	10	13.89	55	43.30
Total	89	100	160	100	72	100	127	100

The number in the table refers to the count of a certain approach to address NOS aspects involved in textbook paragraphs. The percentage in the table is the count of a certain approach to address NOS aspects divided by the total count

Table 10 The content relation of NOS aspects in chemistry textbooks

Content relation	New textbooks-PEP (Chemistry Volume I and Chemistry Volume II)		New textbooks-SSTP (Chemistry Volume I and Chemistry Volume II)		Old textbooks-PEP (Chemistry 1 and Chemistry 2)		Old textbooks-SSTP (Chemistry 1 and Chemistry 2)	
	N	*P*(%)	*N*	*P*(%)	*N*	*P*(%)	*N*	*P*(%)
Content-embedded	85	95.51	133	83.13	70	97.22	114	89.76
Content-generic	4	4.49	27	16.87	2	2.78	13	10.24
Total	89	100	160	100	72	100	127	100

The number in the table refers to the count of a certain content relation of NOS aspects involved in textbook paragraphs. The percentage in the table is the count of a certain content relation of NOS aspects divided by the total count

aspects, which made the research more systematic and in-depth. In this sense, this study has bridged the research gap in the international literature on NOS integrated in science textbooks and echoed with McComas and Olson's (1998) suggestions that curriculum documents in languages other than English, particularly non-western cultures, should be analyzed for NOS aspects. We believe that the relevance of this study will not only be limited to China but could provide the global scientific community with a lens to assess the extent to which attention is paid to NOS in chemistry textbooks and offer information on our progress towards developing the views of NOS. Next, the results presented are discussed in the sequence of the NOS aspects, the approaches to address NOS, and the content relation of NOS aspects order.

With respect to NOS aspects, the proportion of empirical evidence of science was comparatively high, whereas the proportions of creativity and imagination in science, subjectivity in science, and science as a solitary pursuit were comparatively low,

indicating that textbooks paid more attention to classical views of NOS than contemporary views of NOS. On the one hand, this finding supports the fact that positivism is a prevalent paradigm among science educators in China (Wan et al., 2013), as the authors of the four versions of textbooks in this study are all chemistry educators. On the other hand, it may be related to the local culture of China. The Doctrine of the Mean (Zhongyong) is the core of Confucianism which represents the Chinese culture (Qian, 1985). According to Zhao (2000), the Doctrine of the Mean underlines "harmony" (holistic and comprehensive) and stresses that a person's subject and object represent a dialectical unity. These features are greatly different from the classical views of NOS. Qu et al. (2017) have confirmed that the "harmony" element of the Doctrine of the Mean has a negative correlation with the classical views of NOS. It has also been proved by some researches that Chinese students have a poor command of classical NOS under the influence of the Doctrine of the Mean (Liang et al., 2009; Wan et al., 2018). Hence, it is reasonable for the chemistry textbooks to give priority to classical views of NOS in order to help students better grasp them. Moreover, NOS aspects were not evenly addressed in variable chapters or topics, which was similar to the findings of Zhuang et al. (2021) and echoed with Upahi et al. (2020): "while it may be easy to integrate aspect of NOS into some topics and units, for others, it might be a challenge" (p.1335). According to DiGiuseppe (2014), the actual distribution of the NOS representations needs to be tailored based on the features of a textbook's content so that the aspects of NOS can be embedded in proper chapters throughout the book. Thus, it is acceptable that variable chapters or topics address NOS aspects unevenly. Combined with the content of textbooks in the present study, we argued that the following three situations would prompt a chapter or topic to involve more NOS aspects. One is to infiltrate NOS by introducing the formation and development, main features, and research methods of chemical science (e.g., the chapter of "learn about chemical science" in old and new textbooks-SSTP); another is to represent NOS by compiling a detailed history of science related to the subject content (e.g., the topic of "the periodic law of elements"); the third is to highlight NOS by emphasizing the relationship between prediction, evidence, reasoning, and conclusion in exploratory experiments (e.g., the chapter of "properties and transformations of substances" in new textbooks-SSTP). The above three situations can also be regarded as effective strategies for the integration of NOS into textbooks. Additionally, we found that although written based on the same curriculum standards, the textbooks published by PEP and SSTP showed discrepancies in terms of the distribution of NOS aspects. These discrepancies could be attributed to the authors' view and interest in incorporating the aspects of NOS in the textbooks (McComas & Olson, 1998).

In respect of the approaches to address NOS, the most preferred approach was the implicit one. This result was consistent with the findings of Aydin and Tortumlu (2015). Compared to old ones, the proportions of the explicit-reflective and historical-explicit-reflective approaches have increased in new textbooks, but were still not high, which contradicts the position of existing literature that the explicit-reflective approach is more useful for developing NOS understanding than the implicit approach (Khishfe & Abd-El-Khalick, 2002; Lederman, 2007). We argued that this change was to some degree related to the emphasis on the NOS placed by the new curriculum standard (MOE, 2018). However, the new curriculum standard did not set clear requirements for the explicit representations of NOS, which may cause textbook authors to be less aware of addressing NOS explicitly.

The content relation of NOS aspects was dominated by the content-embedded both in new and in old textbooks, which contradicted the findings of Aydin and Tortumlu (2015),

but resembled those of Upahi et al. (2020). Although both content-embedded and content-generic are considered to be effective in dealing with NOS contents (Lederman et al., 2002), Abd-El-Khalick et al. (1998) argued that owing to the fact that most teachers lack the necessary knowledge of NOS and have trouble in the process of teaching NOS, textbooks should clearly provide cases and strategies for integrating NOS into subject contents, and guide teachers to convey and teach NOS in the process of teaching. Hence, the results of this study were acceptable. Moreover, it can be found that new textbooks introduced the aspects of NOS by adding method guide columns or separating the methods and procedures for studying the properties of substances into independent sections, which resulted in an increase in the proportion of the content-generic. We believe that the above way can help students form a more systematic view of scientific methods and the process of scientific research, and have a direct and clear sight of the elements for scientific researches. However, given the abstraction and complexity of NOS, and the cognitive abilities of high school students, this content-generic way should not be utilized too much.

7 Conclusion and Implications

The purpose of this study was to compare the discrepancies in the representations of NOS between new and old chemistry textbooks of Chinese senior high school. To conclude, some positive changes have indeed emerged in the new textbooks, similar to the findings in some other countries (Aydin & Tortumlu, 2015; Chiappetta & Fillman, 2007). These positive changes included the following respects: the NOS aspects were covered more comprehensively; the frequency of NOS aspects has accumulated; the explicit-reflective approach has been paid attention to; specific sections or columns have been established to address NOS. However, there existed some problems. For instance, the proportion of contemporary elements of NOS was still relatively low, and the percentage of explicit-reflective approach and history of science cases have yet to be further increased.

Based on the above conclusions, in order to further improve the quality of chemistry textbooks, textbook authors should sufficiently connect and integrate the NOS aspects in appropriate proportions that could be considered adequate to promote students' scientific literacy. Specifically, authors need to reflect on how to integrate the contemporary elements of NOS into textbooks, with the necessary revisions to offer more explicit NOS aspects and history of science cases. Besides, some NOS activities should be included in new textbooks in order for teachers to implement in class. Activities that help learners understand NOS should be parts of the textbooks. Of course, it should be noted that textbook authors' interest in NOS may largely be dependent on the emphasis placed by curriculum standards. The curriculum standards play a guiding role to authors on the extent to which NOS should be addressed in textbooks. However, unlike in the USA (NGSS Lead States, 2013) and the UK (DFE, 2015), the curriculum standards in China (MOE, 2018) have not yet clearly stated the aspects of NOS and the teaching content and requirements of NOS at each grade level. Hence, clarifying and operationalizing the aspects of NOS should be regarded as the direction for future curriculum standard revision. Furthermore, when textbooks are written in the future, NOS integration should be incorporated in the list of criteria for textbook compilation, which will increase the probability of attracting authors' attention on NOS and its integration into the textbooks. In summary, in order to properly represent the aspects of NOS in textbooks, the groups (i.e., curriculum makers, authors, and researchers) should come together and share their concerns about this topic.

As the analytical framework of this study focused on the pedagogical aspect of NOS, especially the dimensions of approaches to address NOS (Abd-el-Khalick & Lederman, 2000) and the content relation of NOS aspects (Lederman, 2007), we think that the analytical framework, with appropriate revisions, may be applicable to the analysis of classroom teaching, as a tool to characterize teachers' dealing with the NOS. This is a direction for future researches. Specifically, on the basis of converting classroom teaching videos into written transcripts, the aspects of NOS, the approaches to address NOS, and the content relation of NOS aspects employed by teachers can be coded to examine the implementation of NOS education in classroom teaching. Especially in China, the enacted curriculum should be focused on because teachers are not very enthusiastic to emphasize NOS when the education system is dominated by high stake exams (Gu, 2004). Furthermore, with the development of the times, the NOS aspects and the approaches used may change continuously. In the future, emerging and appropriate NOS aspects, and the approaches used, can be taken into consideration and integrated into the analytical framework, thus further developing and innovating this framework.

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Declarations

Conflict of Interest The authors declare that they have no conflict of interest.

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