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Study on the Construction of the Core Literacy Competence System in Chemistry Based on the Delphi Method

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Abstract: Used the Delphi method, the community of 30 experts from the universities and high schools made effective decision-making and authoritative consensus based on the background of China's social development and the overall development needs of students, as well as their own experiences, and obtained that the high school chemistry curriculum should focus on cultivating students' nine key competencies and conceptions that meet the needs of lifelong development and social development.

Keywords: Core literacy; Delphi method; Chemistry course; Key competencies

1. Introduction

In recent years, with the deepening reform of basic education in China, the implementation of the core literacy concept has been promoted. Core literacy permeates all subject areas, and chemistry as an important natural subject is no exception. Core literacy as a key element to deepen the curriculum reform of basic education, enhance national core competitiveness and improve the quality of talent training, the cultivation of students' key literacy enables them to form their own core competitiveness. Therefore, it is the responsibility and mission of the times that our basic education curriculum must undertake to develop students' core literacy in chemistry and equip them with the key abilities and concepts needed to adapt to lifelong development and social development [1]. The current academic community is also paying more and more attention to the research related to core literacy in chemistry, and the research is getting deeper and deeper. This research uses the Delphi method to explore in depth which scientific abilities and values should be cultivated in the secondary school chemistry curriculum through the effective decision-making and authoritative consensus of 30 experts, in order to provide suggestions and insights for the construction of a core literacy system in chemistry and the deepening of chemistry curriculum reform.

2. Research design

This research uses the Delphi method to explore in depth the core question of which key competencies, key issues, and values should be developed in secondary school chemistry curricula from the perspective of students' core literacy.

2.1 Research Method

Delphi method means that the researcher drafted the questionnaire and used e-mail to solicit opinions from the expert group members, and each expert exchanged opinions anonymously with each round of feedback material from the researcher's questionnaire, and after several rounds of feedback (usually 3 to 4 rounds), the experts' opinions were gradually concentrated, and finally the relevant data processing of individual opinions was performed to establish consensus, so as to obtain statistically significant results of the experts' collective judgment [2].In Delphi research, "consensus" is often used as an indicator of study completion. In this research, Osborne defined the threshold score for consensus as "at least 2/3 of the participants rated the item as 4 or higher", i.e., the threshold score on a 5-point scale The threshold score in the 5-point scale is a mean score of more than 3.66 or a plurality of 5, which is considered as consensus [3].

2.2 Expert Selection

The selection of experts plays an important role in the quality of the Delphi method research results. The selected experts need

to have an in-depth understanding of relevant fields, can participate in investigation and research, and have a certain willingness, time, and interest [4]. In accordance with the aims and tasks of this study, the experts selected for this study included candidates from five areas: chemistry master teachers, secondary school principals or vice-principals with a chemistry background, university professors of chemistry, current PhDs in chemistry, and front-line chemistry teachers in secondary schools. Six candidates were selected from each area, for a total of 30 experts. In the Delphi method research, Mitchell [5] thinks that the number of experts should be more than thirteen, and the error reduction of the research is not obvious. Therefore, the thirty experts selected in this research meet the requirements.

2.3 Research process

Four rounds of questionnaires were conducted for this Delphi research, and the research process is shown in Figure 1[6]. The questionnaires were distributed and collected by e-mail, in which the experts did not know each other's identities, and the experts were free and unpressured to participate in the questionnaires.

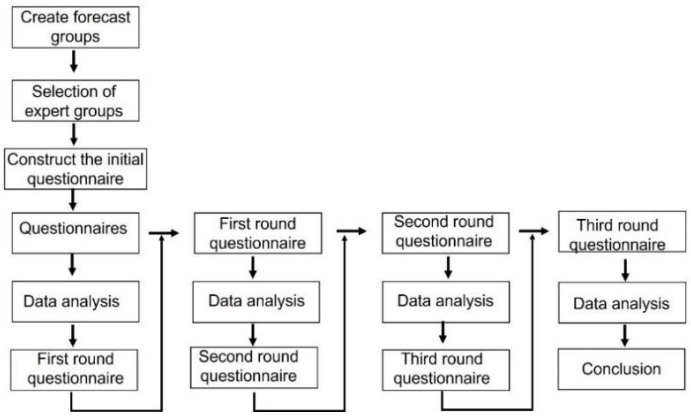

Fig.1 The empirical research process of the Delphi method

2.4 The establishment of initial survey indicators

In this study, to present the multi-level chemistry core literacy as comprehensively as possible, the researcher conducted an in-depth study and comprehensive analysis of relevant academic journal literature and master's and doctoral dissertations in order to find the commonalities between the nodes of the components of the chemistry core literacy competencies. In addition, the author believes that the construction of chemistry core literacy competency system should also be combined with the regularity of students' physical and mental development as well as the requirements of the curriculum objectives put forward by the chemistry curriculum standard. Based on the above thinking, after many exchanges with professors of chemistry curriculum and pedagogy and some senior secondary school chemistry teachers, the following 11 core literacy competencies were initially formulated: the ability to collect, analyze, synthesize, evaluate, and communicate information; the ability to participate in teams, communicate and collaborate; the ability to construct and interpret evidence; the ability to make social decisions; innovation and creativity; the spirit of science; active investigation; a critical attitude; global awareness; independence; and awareness of sustainable development[7-10], and based on this, the initial questionnaire was formulated.

2.5 The first round of questionnaire survey

30 experts were given the 1st round of the Delphi questionnaire and the initial questionnaire feedback report. The questionnaire consisted of 3 sections: (1) Introduction (same as the initial questionnaire). (2) Objective rating questions. There were 13 objective question items. (3) Subjective questions.The analysis of the questionnaires was the same as the initial questionnaire. As can be seen from the results of the processing of the objective scoring questions, the mean score for all Round 1 questionnaire items was over 4. The subjective questions were analyzed by two or more experts who felt that additional items were needed: thinking about the conservation of material change; understanding the interactions between chemistry and life, technology and the social environment; the ability to reason with evidence and construct models; hands-on skills; triple representation thinking; and logical thinking skills. The entries proposed by 2 and more experts were reflected in the objective scoring questions of the Round 2 questionnaire and the Round 1 feedback report was generated.

2.6 The second round of questionnaire survey

The second round of questionnaires was sent to the 30 experts who participated in this study, along with the feedback report from the first round, and the second round contained the following three sections: (1) objective graded questions. 13 scientific

competencies and values and character. (2) Subjective questions. “If you had to choose the 2 most important items from the above, which 2 would you say are the most important? Please write them and give a brief statement of their specific connotations and importance.”

The results of the data analysis showed that the mean scores of all 13 items exceeded 4, and the standard deviations were all <1, indicating that the experts had formed a good consensus on all the entries. For the subjective questions, more than five experts considered “the concept of structure and properties of matter” and “the concept of knowledge of matter and transformation of matter” to be the most important entries, while, after an in-depth and detailed analysis of the experts’ suggestions, The item for “Conceptions of the structure and properties of matter” was replaced by the entry for “Structure, properties, and uses of matter”; “Conceptions of change and equilibrium” and There is a duplication of “thinking about the conservation of change in matter” and, based on the scoring, “thinking about the conservation of change in matter” will be discarded in Round 3 of the questionnaire, refinement and modification of items taking into account the comments of experts. Besides, to make the items more scientific and reasonable, researchers revised and consolidated the items into nine items based on the core literacy of chemistry mentioned in the Chinese General Chemistry Curriculum Standards (2017 Edition), and collated the specific contents of the nine items according to the experts’ statements for their review in the third round of the Delphi survey.

2.7 The third round of questionnaire survey

The third round of questionnaire and the feedback report of the second round of questionnaire were distributed to 30 experts who participated in this research study, and the third round of questionnaire consisted of the following two parts: (1) Objective level rating questions. (2) Subjective questions. This part summarized the specific content of the 9 items elaborated by the experts, who were asked to carefully review and amend or add to them. The data were processed and analyzed using the same criteria as the three rounds of questionnaires above.

3. Result analysis

Through four rounds of Delphi research, we derived the scientific competencies and values items that the expert group believed should be focused on and developed in the secondary school chemistry curriculum. Based on the data collected, the degree of consensus for each item, the variability within and between the expert groups, and the specific connotations of the items were analyzed and elaborated.

3.1 Consensus analysis

The results of the analysis of the data related to rounds 1 and 2 of the Delphi study yielded mean scores of 4 or more for the 9 scientific competence and values items, i.e., all items achieved a good level of expert consensus; The mean scores for the integrated items in Round 3 of the questionnaire were all above 4, indicating a high level of expert consensus on the integrated items[11]. The top ranking was “scientific inquiry and sense of innovation”, with a mean score of 4.90. This was followed by “Macroscopic discernment and microscopic inquiry” and “Scientific spirit and responsibility”, both with an average score of 4.73. The average score for the entries “Concepts of change and balanced thinking”, “Evidence-based reasoning and model perception” and “Chemical safety and green development” was only slightly lower than the first three entries, with an average score of 4.70. The average score for the “Chemical Safety and Green Development” entry was only slightly lower than the first three entries, with an average score of 4.70.

3.2 The specific connotations of the nine items

Through four rounds of Delphi research, we collected the expert group’s interpretation of the connotations of these nine items. Among them, the connotations of “macroscopic identification and microscopic investigation,” “concept of change and balanced thinking,” “evidential reasoning and model cognition,” “scientific inquiry and sense of innovation “The connotations of “scientific spirit and social responsibility” are supplemented by the original expressions of the connotations of core literacy in chemistry proposed in the General High School Chemistry Curriculum Standards (2017 edition), while the connotations of “chemical terms and symbols The entries of “chemical terms and symbols”, “chemical safety and green development”, “teamwork and cooperation”, and “living chemistry and beautiful chemistry” were interpreted by members of the expert group based on real-life needs and their own experiences. The entries of “Chemical Terms and Symbols”, “Chemical Safety and Green Development”, “Team Awareness and Cooperation”, and “Living Chemistry and Beautiful Chemistry” are interpreted by the experts according to the real needs and their own experiences, which are important references for the reform of chemistry curriculum in China.

Table 1 Connotations of nine Scientific capabilities, values and characters

Items	Connotation
Macro-discovery and micro-exploration	Be able to identify, through observation, the macroscopic phenomena of the forms and changes of substances under certain conditions, acquire a preliminary knowledge of the classification of substances and their changes and use symbols to characterize substances and their changes; Be able to understand the links between the composition, structure and properties of substances at the microscopic level and develop the concept that "structure determines properties and properties determine applications".
The concept of change and the idea of balance	Be able to recognize that matter is in constant motion and that changes in matter are conditional; Be able to analyze the chemistry of matter more comprehensively in terms of internal and external causes, quantitative and qualitative changes, etc; Be able to analyze the chemical changes of substances in a more comprehensive way from internal and external causes, quantitative and qualitative changes, pay attention to the transformation of energy in chemical changes, and recognize the conservation of mass and energy in chemical changes.
Evidential reasoning and model cognition	Be able to learn initially to collect a range of evidence and develop possible hypotheses about the properties of substances and their changes; Reason analytically based on evidence to confirm or falsify hypotheses; Can explain the relationship between evidence and conclusions and identify the evidence needed to form scientific conclusions and how evidence can be found; Be able to recognize the links between chemical phenomena and models.
Scientific inquiry and a sense of innovation	Identify and formulate chemistry problems with investigative value, design and optimize experimental solutions based on the purpose of the investigation, complete experimental operations, and process and draw conclusions from experimental information recorded by observation; They will be able to share the results of their experimental investigations with their classmates and suggest ideas for further investigation or improvement of their experiments.
Scientific spirit and social responsibility	Have a sense of lifelong learning and a rigorous and realistic attitude towards science; admire the truth and develop a sense of equality before the truth; Pay attention to social hotspot issues related to chemistry, recognize the importance of environmental protection and rational development of resources, have an awareness of safety, sustainable development of resource conservation and environmental protection and the concept of green chemistry, and be able to participate in social practice activities related to chemistry issues.
Chemical terms and symbolic representations	Awareness at the symbolic level focuses on the chemical language system of elemental symbols, chemical formulae, chemical equations and chemical units of measurement; Know the system of linguistic and non-linguistic symbols (elemental symbols, chemical formulae, chemical equations, atomic structure sketches, etc.) specific to the chemical sciences, be able to interpret their macroscopic and microscopic meanings from the basic chemical symbolic representations and be able to apply the system of chemical terms to communicate.
Chemical safety and green development	To have an awareness of safety in chemical experiments, chemical production and the use of chemical substances, and to understand the handling of some common accidents and emergencies; To develop the concept of "green chemistry" and "responsible care" for the whole society, and to form a simple and moderate, green and low-carbon lifestyle.
Team spirit and cooperative communication	Be able to fully appreciate the importance of the role of the team in the study of chemistry and understand each member of the chemistry team and take an active part in the tasks assigned to the team and fulfilling individual responsibilities. They will be able to take on the tasks assigned to them and fulfill their responsibilities, while communicating fully, discussing collaboratively and working together efficiently.
Living Chemistry and Beauty Chemistry	To be able to understand chemistry in life and to be able to recognize the beauty of chemistry. Through popularizing chemistry and promoting the beauty of chemistry, the public will get to know chemistry, understand chemistry and feel the charm and value of chemistry.

4. Conclusion and Discussion

This Delphi survey collected the perspectives and recommendations of the community of chemistry experts anonymously by mail, and we concluded the following research:

First of all, this Delphi research was conducted over a period of 6 months, and 30 experts were involved in the whole process of 4 rounds of questionnaires in full, which ensured the reliability of the study. At the same time, many experts believe that this research has a highly important significance, and the Chinese General High School Chemistry Curriculum Standards (2017 edition) put forward five aspects of core literacy in chemistry, from the theoretical level, the five aspects of core literacy in chemistry announced in China are mainly summarized and released by experts in chemistry and curriculum theory in colleges and universities combined with relevant theories, however, the opinions of the majority of front-line teachers, as the implementers of the policy, have not been fully considered. Therefore, based on the combination of theories such as triple representation and quadruple representation, this research integrates university researchers as well as front-line teachers in secondary schools, the research on core literacy in chemistry carried out simultaneously with the national core literacy in chemistry, and with the support of data, four aspects of core literacy in addition to the five aspects promulgated by the country were obtained, which is of great significance for the relevant research on core literacy

in chemistry in China, and also has an important inspiration role for the reform and development of the secondary school chemistry curriculum in China.

Secondly, this research has gained a consensus among a community of domestic experts on the question of "which scientific skills and values should be developed in the secondary school chemistry curriculum". Among the nine items generated at the end, in addition to the core literacy of chemistry mentioned in the General High School Chemistry Curriculum Standard (2017 edition), which received a high consensus from the expert group, the researcher of this topic carefully discussed and summarized the items of "chemical terms and symbolic representation", "chemical safety and green development", "team consciousness and cooperative communication", and "living chemistry and beautiful chemistry", and the expert group also gave high average scores to these four items, which means that the secondary school chemistry curriculum should pay enough attention to these items.

Finally, we elaborated on the connotations of the nine items. From the elaboration of the connotations of each item, we can see that there are certain connections and intersections between some items, for example, "chemical terminology and symbolic representation" and "macroscopic identification and microscopic analysis", "chemical safety and green development" and "scientific spirit and social responsibility" are necessarily related to each other. The reason for broken down and discussed in this research is only to better elaborate their respective prominent connotations and thus better construct a core literacy system for students in chemistry, and it does not mean that these items are to be expressed, communicated and practiced in chemistry education in isolation. Through this Delphi empirical research and repeated evaluation by the experts, we can conclude that, in addition to the core literacies of chemistry mentioned in the General High School Chemistry Curriculum Standard (2017 Edition), "chemical terms and symbolic representation," "chemical safety and green development," "team consciousness and cooperative communication," and "living chemistry and beautiful chemistry" should also become the key literacies of chemistry to be cultivated in the secondary school chemistry curriculum, and the nine items are interrelated, interact with each other and guide the practice of chemistry curriculum reform.

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