Chen *et al. Discip Interdscip Sci Educ Res* (2024) 6:2
https://doi.org/10.1186/s43031-023-00091-4

Disciplinary and Interdisciplinary Science Education Research

RESEARCH

Open Access

An analysis of Chinese chemistry curriculum standards based on OECD Education 2030 Curriculum Content Mapping

Xiaoge Chen[1], Lei Wang[1,2*], Xin Shao[3] and Rui Wei[1,2]

Abstract

The development of students' core competencies for the future society has become a shared goal in curriculum reform worldwide. Efforts are being made to investigate which core competencies should be cultivated and how they relate to the curriculum content. Specifically, designing core competency-oriented intended curriculum and translating it into implemented curriculum are common concerns and challenges encountered by countries during curriculum reform. In order to promote mutual sharing and learning among different countries and regions, the Organization for Economic Co-operation and Development (OECD) developed an analytical comparison framework and standards based on The Future of Education and Skills project. This study conducted a comparison between the 2011 edition and 2022 edition of the Compulsory Education Chemistry Curriculum Standards (CECCS) for students in grade 7 to grade 9. It identified 737 coding units for five learning themes and conducted a specific analysis and comparison using the Curriculum Content Mapping (CCM) and Theme Content Mapping (TCM). Heat maps are generated to reflect the correlation between China's grade 7 to grade 9 CECCS and the twenty-eight competencies identified in the OECD project, as well as the main emphasis before and after the revision of the curriculum standards. A mixed research method of qualitative and quantitative analysis was conducted to explore the characteristics of Chinese chemistry curriculum structure. This study provides insights into experiences regarding embodying core competencies, designing competency-oriented intended curriculum, and providing guidance for curriculum implementation in grade 7 to grade 9. It allows both teachers and educators to identify areas for improvement.

Keywords Compulsory Education Chemistry Curriculum Standards, Chemistry Education, OECD competency, Curriculum Content Mapping, Theme Content Mapping

Introduction

The development and changes in society have a significant impact on our personal lives, encompassing factors such as globalization, cultural diversity, artificial intelligence, and technological advancements. These changes create a need for individuals to be adaptable and resilient in the face of constant change. Consequently, education systems are under pressure to better prepare students for the future by empowering them with the necessary competencies to shape their lives and make meaningful contributions to society. As a result, competency is seen as a meaningful goal for science education in general and chemistry education in particular. Competency-oriented education focuses on equipping students with the necessary knowledge and skills to complete future tasks and activities. Efforts have been made to incorporate real-world practices that drive learning (Brassler & Dettmers, 2017), including active interaction, collaboration,

*Correspondence:
Lei Wang
bnuchemistry@126.com
[1] College of Chemistry, Beijing Normal University, Beijing, China
[2] Research Institute of Science Education, Beijing Normal University, Beijing, China
[3] Educational Science Publishing House, Beijing, China

communication, and reflection (Kokotsaki et al., 2016). Specifically, competency outlines the knowledge and skills that students should possess upon completing a task. This aligns with the Ministry of Education's vision for inclusive and competency-based school education (MoE, 2022).

Notably, curriculum standards play an important role in achieving competency-oriented education by converting the intended curriculum into desired outcomes. The official curriculum documents establish educational standards and defining content, objectives, and assessment patterns for each discipline (Wei & Ou, 2019). They serve as the foundation for curriculum development, classroom instruction, and examinations. The importance of curriculum standards in bridging the gap between school teaching and student learning is widely acknowledged (Chen et al., 2019). In secondary school, curriculum standards act as guiding principles for educators and teachers, outlining the essential knowledge, skills, and competencies students should acquire at different grade levels. Efforts have been made regarding curriculum research in various areas of education, including assessment techniques, instructional materials, and teaching methods. For example, Nasir (2021) conducted research on curriculum development in traditional Islamic schools in Indonesia, focusing on school accreditation standards. Wang et al. (2022) performed a curriculum assessment using the Subject Competency Framework (Wang, 2016) to assess students' comprehension of a specific theme. Chen et al. (2018) explored the curriculum emphasis and curriculum orientation within the same Chinese cultural background. Khaddoor et al. (2017) analyzed the intended curriculum across seven Arabic countries, while Gervedink et al. (2013) identified cultural influences on curriculum implementation. Vojíř and Rusek (2019) reviewed research trends in science education textbooks over an 18-year period. Such curriculum research plays a vital role in education, particularly in diverse educational settings. By examining the existing body of knowledge, educators and teachers can better support student achievement and academic success.

Despite the increasing research efforts dedicated to enhancing the engagement and relevance of school science (Erduran & Dagher, 2014; Stuckey et al., 2013a, 2013b), as well as implementing teaching methods that utilize traditional or unconventional media to teach relevant science topics (Belova & Eilks, 2015), two crucial issues persist in the implementing of the curriculum. Firstly, there is a mismatch between curriculum content and assessment. Teachers often prioritize teaching topics emphasized in high-stakes exams, potentially neglecting content that is not assessed (Ma, Fulmer, Liang, Chen, Li & Li., 2013). Secondly, there is a disconnect between the teaching practices and the underlying theories of learning and instruction in the new curriculum. Despite teachers generally endorsing the principles of the new curriculum and standards, they still rely on conventional chemistry frameworks and teacher-centered instructional approaches. Therefore, to ensure the success of competency-oriented and standards-based science education reform, it is crucial to assess the quality of curriculum and standards.

Literature review

Competency-oriented education in the global context

In 2015, the Organization for Economic Co-operation and Development (OECD) launched The Future of Education and Skills project to map the future of education. The project aims to identify a) students' knowledge, skills, attitudes, and values that they need to achieve a better life by 2030, and b) an instructional system that can effectively develop these knowledge, skills, attitudes, and values (Meng, 2018). In cooperation with policymakers, academic experts, teachers, students, and social partners, the OECD finalized a corresponding position paper called The Future of Education and Skills Education 2030 in 2018 (OECD, 2018). This project explores long-term challenges in education and contributes to the design of more systematic and evidence-based curricula, making it a significant global trend in curriculum reform. Consequently, high-quality instructional materials, including curriculum standards and textbooks, are developed to foster students' essential knowledge and skills in response to the "OECD Learning Framework 2030"(OECD, 2018). These efforts promote international cooperation and collaboration, facilitating the development of effective and evidence-based curriculum standards worldwide.

Competency-oriented curriculum reform in the Chinese context

China is facing the important question of how to effectively prepare its students for an unpredictable and uncertain future. Due to different cultural contexts and historical backgrounds, China exhibits diverse patterns and traditions in science curriculum development compared to other countries. Specifically, China has a centralized system for compulsory education, which includes specific chemistry curriculum standards and corresponding textbooks.

To date, the Compulsory Education Chemistry Curriculum Standards (CECCS) was released by Ministry of education in 2011 in China (MoE, 2011). Over the last ten years, the 2011 CECCS had guided chemistry education in nationwide lower secondary schools. In 2019, the Ministry of Education of the People's Republic of China initiated a new round of curriculum reform

for compulsory education (Grades 1–9) (MoE, 2019). Subsequently, a version of the chemistry curriculum standard for compulsory education was released in April 2022 (MoE, 2022). In response to the curriculum reform, educational stakeholders strive to ensure that students receive a competency-oriented education that meets the evolving needs of the twenty-first century.

The rationale of Chinese context to the global context

The OECD Education 2030 Curriculum Content Mapping (CCM), based on the OECD Learning Compass 2030 documents (OECD, 2019a), serves two important purposes. Firstly, it provides countries worldwide with an evidence-based approach for self-reflection. Secondly, it allows countries to learn from each other by sharing the findings of their proposed curriculum. The CCM and TCM identify core competencies and explore how competencies can be transformed into curriculum by mapping the experiences and practices in different countries.

In this regard, China has made efforts to demonstrate how Chinese chemistry curriculum standards contribute to mapping students' core competencies. The analysis of the 2011 edition and 2022 edition of the Compulsory Education Chemistry Curriculum Standards (CECCS) aims to: a) assess which core competencies are reflected in the competency-oriented curriculum that addresses the changing needs of students and society; b) evaluate the extent to which current national curriculum standards can meet students' need of the future for the aforementioned functions; c) offer experiences regarding how core competency-oriented intended curriculum guide implemented curriculum; d) provide stakeholders with an opportunity to identify areas for improvement to enhance the quality and relevance of education. This study shed light on experiences in designing competency-oriented curriculum and explores the ways in which curriculum standards facilitate competency development.

Research questions

This study focused on analyzing curriculum standards to explore details about the transformation of the Chinese curriculum. The latest official version of Compulsory Education Chemistry Curriculum Standards (2022 CECCS) and the prior one (2011 CECCS) were chosen as the research sample.

By analyzing both versions of the CECCS (2011 and 2022) in accordance with the suggestions of OECD's future of education and skills 2030 (OECD, 2018) and Curriculum Content Mapping (OECD, 2019), this study aims to explore:

1. What are the similarities and differences in the curriculum content structure between the 2011 and 2022 CECCS?
2. What are the levels of curriculum alignment (e.g. breadth, depth) of 2011 and 2022 CECCS compared to the OECD Learning Framework 2030?
3. What are the similarities and differences of learning area focus regarding the 2011 and 2022 CECCS?

Theoretical framework

In response to education queries, the Future of Education and Skills Education 2030 project developed the OECD Learning Compass 2030 (OECD, 2019b), a "roadmap" that set out an ideal version of education in 2030. It emphasized the value of formal and non-formal learning opportunities that take place at school or in the community. The Learning Compass 2030 is OECD's initial attempt to create a "roadmap" for curriculum reform. It is claimed by the OECD as a "learning framework" that provides a broad range of competencies in which students are expected to obtain. Simultaneously, assessment projects are suggested to use this learning framework to help e.g. assessing students' progress in a particular context.

After two years of study with 14 countries, OECD designed the OECD Education 2030 Curriculum Content Mapping (CCM) based on the OECD Learning Compass 2030 (OECD, 2019a). This project aimed to explore how knowledge is intended to be taught together with skills. The scope is to identify 1) the way other countries incorporate various competencies and the breadth, depth as well as dimensions of various competencies; 2) the relationships between knowledge, skills, values, and attitudes in certain learning areas (OECD, 2019a).

The OECD's CCM competencies can be grouped as "foundational literacies", "skills/attitudes/values", "key concepts of the learning framework", "transformative competencies and competency development for 2030", and "compound competencies for 2030", with each category containing several sub-categories (Table 1) (Wang et al., 2021). A total of twenty-eight competencies are provided as the OECD competencies.

Method

Qualitative and Quantitative data of the Chinese curriculum documents were extracted and analyzed based on the Curriculum Content Mapping (CCM) project (OECD, 2019a). All curricula documents were obtained from the official government website. The analysis includes four steps.

Step 1: Item coding

All the curriculum standards were examined page by page. The contents and texts of the curriculum

Table 1 Curriculum content map for competency framework

Category	Subcategory
Foundational literacies	• Literacy • Numeracy • ICT literacy/Digital literacy • Data literacy • Physical/Health literacy
Skills, Attitudes &Values	• Cooperation/Collaboration • Critical thinking • Problem-solving • Self-regulation/Self-control • Empathy • Respect • Persistence/Resilience • Trust • Learning to Learn
Key concepts	• Student agency • Co-agency
Transformative Competencies and competency development for 2030	• Creating new value • Taking responsibility • Reconciling dilemmas and tensions • Anticipation • Action • Reflection
Compound Competencies for 2030	• Global competency • Media literacy • Literacy for sustainable development • Computational thinking/Coding/Programming • Financial literacy • Entrepreneurship

standards were read carefully and repeatedly until the entire frame structure becomes apparent. Each sentence of the 2011 and 2022 CECCS curriculum content was coded as a separate coding unit during the analysis. When a sentence did not contain specific learning objectives or student competency requirements, it was not included in the coding.

Step 2: Aligning each coding unit with the OECD competencies

The relevant coding unit was aligned with the twenty-eight OECD competencies described in Table 1, and the level of correspondence was divided into levels 1, 2, 3, and 4 according to Table 2. The criteria, which demonstrate the expected level of competency attainment by students, were presented in Table 2 (adapted from OECD, 2019a).

Step 3: CCM and TCM analysis

The relevant coding unit was coded according to the CCM subject coding framework (OECD, 2019a) to explore the learning area focus of each coding unit (Table 3). The criteria ranged from natural science chemistry 1 to 7 (NSC1 to NSC7).

Step 4: Developing the heat map

Undertake the mapping process to develop heat maps of the 2011 and 2022 CECCS. The final representation level of each OECD competency was determined by selecting the highest level of representation from the corresponding coding units. For instance, after Step 3, if all coding units that have been categorized as NSC 1 indicate a "literacy" competency level of 3 (the highest), then the corresponding table cell in the heat map is marked as 3. An example of the overall coding process can be seen below (Table 4).

There are five themes in the 2011 CECCS and five themes in the 2022 CECCS. The page numbers for the CECCS in 2011 and 2022 are 63 and 80 respectively. A total of 737 coding units were analyzed. Data collection was achieved through several rounds of initial theme coding, item screening, and interpretation. A mixed qualitative and quantitative research method was used. Qualitative data were generated through content analysis (Zhang et al., 2019). The quantitative analysis aimed to develop a two-dimensional heat map of the 2011 CECCS and 2022 CECCS. Reliability analyses were conducted by all authors. Independent coding was carried out by two coders with an initial 82% inter-rater agreement to a final 90% inter-rater agreement after negotiating disagreements.

Findings

This study aims to conduct a comparison of Chinese Compulsory Education Chemistry Curriculum Standards based on OECD's Future of Education and skills 2030. The 2011 and 2022 Compulsory Education Chemistry Curriculum Standards (CECCS) are screened and analyzed to explore the curriculum content structure, learning area focus, and alignment with OECD competencies.

Similarities and differences of curriculum content structure

By comparing the content of the two CECCS released in 2011 and 2022, it can be seen that both versions include five themes. Moreover, the 2022 CECCS adapts its content structure compared to that of the 2011 CECCS (Table 5).

Table 5 shows that both the 2011 and 2022 CECCS have similar themes, but the secondary topics within each theme are constructed in a different way. The 2011 CECCS mainly focused on fundamental knowledge (Theme 1–5), while the 2022 CECCS introduced a five-dimensional BCMAP content structure, which includes

Table 2 Criteria of the corresponding level

Level	Category	Illustration	Example	OECD competency & level
1	Not targeted in the curriculum	The competency is not included in the curriculum standard and it is unlikely that teachers would include it in their teaching	Debate: Understand the history of chemical science (page 12, 2022 CECCS)	Trust: Level 1
2	Not targeted in the learning area but teachers might include it when teaching this learning/subject area	The competency is not explicitly included in the curriculum standard of the learning/subject area, but there are opportunities for teachers to include the competency by referring to recommended textbooks/ policy documents	Collect weekly/daily reports of local air quality or related information from newspapers, TV, or other media over a period of time, and analyze the reasons. (page 31, 2011 CECCS)	Media literacy: Level 2
3	Sub-target of the learning area in specific subjects only with no explicit demonstration (e.g., sub-objective)	The competency is included in the curriculum standard but only as a sub-objective or the selected competencies are not demonstrated in the curriculum	Investigate household cleaners, disinfectants , including their types and common problems related to their use (page 35, 2022 CECCS)	Problem solving: Level 3
4	Sub-target of the learning area in specific subjects only with explicit demonstration (e.g., main objective)	The competency is included in the curriculum standard as the main objective of the selected competencies is clearly articulated in the curriculum	Debate: Are chemicals good or bad for human health? (page 30, 2011 CECCS)	Physical/health literacy: Level 4
N/A	Not applicable	The content area does not apply to the country's curriculum	-	-

Table 3 CCM subject coding framework of natural science chemistry (based on OECD, 2019b)

Criteria	Contents/Activities	Example
NSC1	Atoms, elements, compounds, chemical reactions, the periodic table, organic chemistry, properties and uses of fluids, and the laws of chemistry	Recognize the composition of water (page 18, 2022 CECCS)
NSC2	The safe use of chemicals	Explore scientific issues like the appropriate use of combustible substances like alcohol (page 30, 2022 CECCS)
NSC3	Activities involving e.g. investigation processes, practices, and procedures in chemistry: the formulation of scientific questions and solutions; the investigation of causes, the formulation of hypotheses and hypotheses testing; data/evidence interpretation and presentation following investigation/experimentation	Examine the changes that occur as a copper sheet burns in the air (page 17, 2022 CECCS)
NSC4	Activities involving e.g. planning and conducting safe and rigorous investigations in chemistry	Investigate and analyze the reasons for local air quality changes in recent years (page 17, 2022 CECCS)
NSC5	The work of scientists in chemistry, how to think like scientists in chemistry, and how chemistry contributes to and relates to real life and the real world	Hou Debang's contribution to China's alkali industry (page 22, 2022 CECCS)
NSC6	Moral and ethical issues in chemistry	The awareness of scientific ethics and compliance with laws and regulations in interdisciplinary practice (page 33, 2022 CECCS)
NSC7	Concepts related to global citizenship and sustainable development education, including environmental sustainability; education for international understanding, cooperation, and peace; and education relating to human rights and fundamental freedoms	Establish a sustainable development philosophy of peaceful coexistence between man and nature (page 31, 2022 CECCS)

Table 4 The overall coding process

Phase	Coding approach	Example	Coding result
Step 1	Item coding	Investigate the conditions of combustion (2022 CECCS, page 27)	-
Step 2	CCM analysis	Recognize that substance changes accompany the process of energy change, and the transformation of substances can be achieved through chemical reactions under certain conditions; Recognize quantitative correlations exist between substances in chemical reactions and develop an initial cognition of transformation (2022 CECCS, page 26)	NSC 1
Step 3	Aligning each coding unit with the OECD competencies	Design and develop computer programs that can be used to investigate combustion conditions and quantitative relations of chemical relations (2022 CECCS, page 30)	Computational thinking/Coding/Programming
Step 4	Developing the heat map	Design and develop computer programs that can be used to investigate combustion conditions and quantitative relations of chemical relations (2022 CECCS, page 30)	Level 4

Big idea (B), Core knowledge (C), Method (M), Applying and Attitude (A), and Practice (P) (Table 5).

Generally, each theme provided the main idea and requirements of core competency through the Big idea (B). Big Idea (B) and Core knowledge (C) work together to enhance the understanding and requirements of basic chemical concepts within each theme. The Method (M) reflects the developmental requirements of scientific thinking, while the Applying and Attitude (A) emphasizes the cultivation of scientific attitudes and responsibilities. Collectively, students learn Core knowledge (C), develop scientific Method (M), form scientific values and Applying and Attitude (A), and construct corresponding Big ideas (B) by conducting compulsory experiments and interdisciplinary tasks/activities to meet the academic requirements set by each theme.

Specifically, Fig. 1 demonstrates the organization of Theme 4 (2022 CECCS) (Table 5) according to the BCMAP model. In the 2022 CECCS, the Big idea (B) of theme 4 is " 4.1 changes and transformations of substance", which provides an initial understanding of chemical change and quantitative relations between substances in chemical reactions. Core knowledge (C) focuses on " 4.2 chemical reactions and the law of conservation of mass", which includes topics such as 1) characteristics of chemical changes and basic chemical reactions; 2) quantitative relationships and the law of conservation of mass of chemical reactions. Method (M) describes "4.3 ideas and methods for recognizing

Table 5 Curriculum content structure

2011 CECCS	2022 CECCS
Theme 1: Scientific inquiry	**Theme 1: Scientific Inquiry and practical work**
1.1 Promote the understanding of scientific inquiry	1.1 The nature of chemistry science **(B)**
1.2 Develop scientific inquiry skills	1.2 Experimental inquiry **(C)**
1.3 Learn basic laboratory skills	■ Scientific inquiry
1.4 Complete basic student experiments	■ Basic chemical laboratory skills
Theme 2: Chemical substances around us	1.3 Chemistry experimental inquiry ideas and methods **(M)**
2.1 The air around us	1.4 Scientific inquiry attitudes **(A)**
2.2 Water and common solutions	1.5 Students' compulsory experiments and practical activities **(P)**
2.3 Metals and metallic minerals	**Theme 2: Matter property and application**
2.4 Common compounds in life	2.1 The diversity of substances **(B)**
Theme 3: Marvelous matter composition	2.2 Common substances **(C)**
3.1The diversity of chemical substances	■ Air, oxygen, carbon dioxide
3.2 Particles form the substance	■ Water and solutions
3.3 Recognize chemical elements	■ Metals and metallic minerals
3.4 Representation of substance's composition	■ Acids, bases, and salts
Theme 4: Chemical changes in substances	2.3 Ideas and methods for recognizing the properties of substances **(M)**
4.1 The basic characteristics of chemical changes	2.4 The extensive use of substances' properties and the proper use of chemicals **(A)**
4.2 Recognize several types of chemical reactions	2.5Compulsory students' experiments and practical activities **(P)**
4.3 Conservation of mass	**Theme 3: Matter Composition and Structure**
Theme 5: Chemistry and social development	3.1 Matter composition **(B)**
5.1 Chemistry and the Use of Energy and Resources	3.2 Elements, molecules, atoms, and matter **(C)**
5.2 Common synthesized chemical materials	■ Elements
5.3 Chemical substances and health	■ Molecules and atoms
5.4 Protect our environment	■ Representation of the matter composition
	3.3 Ideas and methods for recognizing the composition and structure of substances **(M)**
	3.4 The research significance of the composition and structure of substances **(A)**
	3.5 Compulsory students' experiments and practical activities for students **(P)**
	Theme 4: Chemical changes in substances
	4.1 Changes and transformations of substance **(B)**
	4.2 Chemical reactions and the law of conservation of mass **(C)**
	■ Characteristics of chemical changes and basic chemical reactions
	■ Quantitative relationships and the law of conservation of mass of chemical reactions
	4.3 Ideas and methods for recognizing chemical reactions **(M)**
	4.4 The application value of chemical reactions and reasonable regulation **(A)**
	4.5 Students' compulsory experiments and practical activities **(P)**
	Theme 5: Chemistry and society · Interdisciplinary practice
	5. 1 Chemistry and Sustainability **(B)**
	5.2 Chemistry and resources, energy, materials, environment, and health **(C)**
	5.3 Ideas and methods for the integration of chemistry, technology, and engineering to solve interdisciplinary problems **(M)**
	5.4 Meeting the challenges of an uncertain future **(A)**
	■ Scientific ethics and legal norms
	■ Reasonable Responses to social scientific issues
	5.5 Interdisciplinary practical activities **(P)**

chemical reactions", e.g. "*develop the ability to think systematically about chemical reactions*" (page 27, 2022 CECCS). Attitudes (A) emphasizes "4.4 The application value of chemical reactions and reasonable regulation", which includes requirements such as "*establish resource recycling and green environmental awareness*" *(page twenty-eight, 2022 CECCS)*. Practice (P) provides "4.5 students' compulsory experiments and practical activities", which includes e.g. "*interdisciplinary practical activities*" and "*investigation of combustion conditions*" *(page twenty-eight, 2022 CECCS)*. Students are encouraged to design and conduct creative interdisciplinary projects and practical activities in real-life contexts based on their chemistry knowledge.

In summary, the 2022 CECCS outlines a five-dimensional BCMAP content structure to enhance students' core competency. The incorporation of BCMAP in the new 2022 CECCS demonstrates a significant improvement compared to the previous 2011 CECCS. Figure 1 provides an overview of the BCMAP model of Theme 4 to help understand the content structure of 2022 CECCS, similar ideas can be found in all the other themes of the 2022 CECCS.

Curriculum alignment

To investigate the alignment of curriculum content between the 2011 and 2022 CECCS, "heat maps" depicting the curriculum content mapping (CCM) and theme

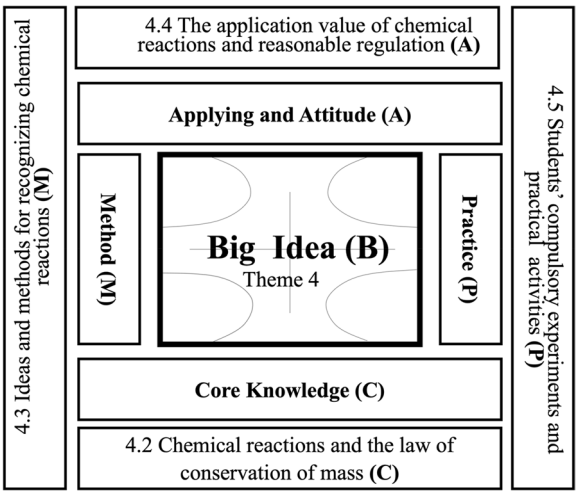

Fig. 1 BCMAP model used in 2022 CECCS (adapted from Wang, 2022)

content mapping (TCM) are created. The CCM and TCM heat maps illustrate the general structure of the 2011 CECCS and 2022 CECCS, respectively. Coding units are analyzed to determine the alignment of the CECCS with the twenty-eight OECD competencies (Tables 6, 7, 8 and 9).

CCM heat map of 2011 CECCS

Table 6 provides an overview of the CCM heat map for the 2011 CECCS. It shows that the 2011 CECCS demonstrates a certain relation to the OECD competencies. Notably, the competencies of "Transformative Competencies and Competency Development for 2030" and "Foundational literacies" are more prominent compared to the other three competencies. There is also some relevance observed with the competencies of "Key concepts" and "Skills, Attitudes & Values for 2030" in relation to the 2011 CECCS. However, "Compound competencies for 2030" tends to be less prominent among all other OECD competencies.

In terms of "Foundational literacies," the 2011 CECCS reveals "literacy" as the most targeted competency at a main level. Additionally, "numeracy," "ICT literacy/digital literacy," "data literacy," and "physical/health literacy" are addressed at certain levels, but less strong than "literacy". However, when considering "Skills, Attitudes & Values for 2030," the 2011 CECCS includes "cooperation/collaboration" and "problem-solving" as the main targets. "Critical thinking", "respect", and "learning to learn" are rated to some extent, while "self-regulation/self-control" and "persistence/resilience" are absent.

Concerning "Key concepts", "student agency" and "co-agency", both of them shows certain levels of inclusion. Regarding "Transformative Competencies and Competency Development for 2030", the 2011 CECCS takes "action" as the most rated main-target competency. Additionally, "taking responsibility" and "reconciling dilemmas and tensions" are included to a similar extent. However, there is a need to enhance the focus on "creating new value".

In terms of "Compound competencies for 2030", it mainly applies to "literacy for sustainable development". Additionally, "financial literacy" and "entrepreneurship" can also be found in the 2011 CECCS. However, "media literacy" and "computational thinking/coding/programming" are absent.

CCM heat map of 2022 CECCS

The 2022 CECCS shows a higher alignment with the OECD competencies (Table 7). Results show that all categories, including "Foundational literacies", "Skills, Attitudes & Values for 2030", "Key concepts", "Transformative Competencies and Competency Development for 2030", and "Compound competencies for 2030" demonstrate a higher level of relation to the curriculum content.

In terms of "Foundational literacies", the emphasis is placed more on "literacy". In the "Skills, Attitudes & Values for 2030" category, the 2022 CECCS seems to include several of the competencies, e.g. "cooperation/collaboration", "critical thinking", "problem-solving", "respect", "trust", and "learning to learn" as main targeted competency. However, "self-regulation/

Table 6 CCM heat map of 2011 CECCS

2011	Foundational Literacies					Skills, Attitudes & Values for 2030									Key Concepts		Transformative Competencies and Competency Development for 2030						Compound competencies for 2030					
	Literacy	Numeracy	ICT literacy /Digital literacy	Data Literacy	Physical/health literacy	Cooperation/ collaboration	Critical thinking	Problem solving	Self-regulation/ self-control	Empathy	Respect	Persistence/resilience	Trust	Learning to Learn	Student Agency	Co-agency	Creating new value	Taking responsibility	Reconciling dilemmas and tensions	Anticipation	Action	Reflection	Global Competency	Media literacy	Literacy for Sustainable Development	Computational thinking /coding/programming	Financial literacy	Entrepreneurship
NSC1	3	3	3	3	3	2	1	1	1	1	1	1	1	3	1	2	2	2	1	1	4	1	2	1	2	1	1	3
NSC2	3	1	1	1	4	1	2	1	1	2	3	1	2	1	1	4	1	1	2	1	3	1	2	1	4	1	1	1
NSC3	4	4	1	3	1	3	3	4	1	2	3	1	2	3	4	4	1	3	4	3	4	3	2	1	1	1	1	2
NSC4	4	3	3	2	3	2	1	3	1	1	3	1	2	1	1	2	2	4	4	1	4	1	2	1	3	1	3	3
NSC5	1	3	1	1	3	4	1	1	1	1	3	1	1	3	1	2	2	4	2	1	1	1	2	1	3	1	2	1
NSC6	1	1	1	1	2	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	2	1	3	1	1	1
NSC7	4	1	3	2	1	1	1	1	1	1	1	1	2	1	1	1	2	1	1	1	4	1	2	2	3	1	2	1

Table 7 CCM heat map of 2022 CECCS

2022	Foundational Literacies					Skills, Attitudes & Values for 2030								Key Concepts		Transformative Competencies and Competency Development for 2030					Compound competencies for 2030					
	Literacy	Numeracy	ICT literacy /Digital literacy	Data Literacy	Physical/health literacy	Cooperation/ collaboration	Critical thinking	Problem solving	Self-regulation/ self-control	Empathy	Respect	Persistence/resilience	Trust	Learning to Learn	Student Agency	Co-agency	Creating new value	Taking responsibility	Reconciling dilemmas and tensions	Anticipation	Action	Reflection	Global Competency	Media literacy	Literacy for Sustainable	Computational thinking /coding/programming	Financial literacy	Entrepreneurship
NSC1	4	4	4	4	1	4	4	4	1	3	4	1	4	4	3	3	4	1	4	4	4	4	3	4	3	4	3	3
NSC2	3	1	1	1	4	3	3	4	4	3	3	2	4	4	3	4	1	4	4	3	4	4	1	3	1	1	1	3
NSC3	4	4	4	4	4	3	4	4	3	3	4	3	3	4	4	4	4	4	4	4	4	4	4	3	4	1	1	3
NSC4	4	1	4	3	3	4	3	4	3	3	3	1	4	2	2	3	3	3	4	4	4	3	3	4	4	1	4	3
NSC5	4	1	4	1	4	4	4	4	1	3	4	4	4	4	4	4	4	3	4	3	4	4	3	4	4	1	1	3
NSC6	4	1	1	1	3	1	1	3	3	1	3	1	3	3	3	4	1	4	4	1	4	3	3	3	3	1	1	3
NSC7	4	2	4	3	4	1	3	4	1	3	4	1	1	4	4	3	4	4	4	3	4	4	3	4	4	2	4	3

self-control" and "persistence/resilience" can be found at a lower inclusive degree.

Concerning "Key concepts", "co-agency" and "student agency" are enhanced by the 2022 CECCS. Further data indicates that "reconciling dilemmas and tensions" as well as "action" are considered as main targets within the "Transformative Competencies and Competency Development for 2030" of the 2022 CECCS. Importantly, this new curriculum standards also place increased emphasis on "creating new value" and "reflection", which were insufficient in the 2011 CECCS.

Concerning "Compound competencies for 2030", it is noteworthy that the 2022 CECCS places increased emphasis on "media literacy" and "financial literacy". However, the inclusion of "computational thinking/coding/programming" is suggested with limited inclusion.

Summary of CCM heat map regarding 2011 and 2022 CECCS

In summary, development and changes in alignment with the OECD competencies from 2011 to 2022 can be seen through two CCM heat maps (Tables 6 and 7. Generally, the 2011 CECCS incorporates "Foundational literacies" and "Transformative Competencies and Competency Development for 2030" as two out of the five most targeted competencies. In addition, the data for "Compound competencies for 2030" indicate that this competency is given less emphasis compared to other competencies. This means the 2011 CECCS places a significant emphasis on students' reading and writing competency, particularly in terms of their ability to assess texts (belongs to "Foundational literacies") as well as being able to take action for a specific goal and acting responsibly (belongs to "Transformative Competencies and Competency Development for 2030"). Moreover, the competency of digital learning (belongs to "Compound competencies for 2030") is limited in the 2011 CECCS.

The 2022 CECCS includes the majority of the twenty-eight competencies as main targets. Notably, there is a significant enhancement in the inclusion of "Compound competencies for 2030", which was insufficient in the 2011 CECCS. In addition, the 2022 CECCS requires corresponding competencies in various tasks assigned to students. For example, it emphasizes "Transformative Competencies and Competency Development for 2030" regarding media news, problem-solving solutions utilizing computational techniques, which fall under the category of "Compound competencies for 2030".

TCM heat map of 2011 CECCS

Table 8 displays the Theme Content Mapping (TCM) of the 2011 CECCS. It is analyzed to explore the relevance of OECD competencies with five 2011 CECCS themes.

Table 8 TCM heat map of 2011 CECCS

2011	Foundational Literacies					Skills, Attitudes & Values for 2030								Key Concepts		Transformative Competencies and Competency Development for 2030					Compound competencies for 2030					
	Literacy	Numeracy	ICT literacy /Digital literacy	Data Literacy	Physical/health literacy	Cooperation/ collaboration	Critical thinking	Problem solving	Self-regulation/ self-control	Empathy	Respect	Persistence/resilience	Trust	Learning to Learn	Student Agency	Co-agency	Creating new value	Taking responsibility	Reconciling dilemmas and tensions	Anticipation	Action	Reflection	Global Competency	Media literacy	Literacy for Sustainable	Computational thinking /coding/programming	Financial literacy	Entrepreneurship
Theme 1	4	3	1	3	1	4	3	4	1	2	3	1	2	3	4	4	1	3	3	3	4	3	1	1	1	1	1	1
Theme 2	4	3	3	3	3	2	1	3	1	1	3	1	1	1	1	2	2	2	4	2	4	1	2	1	2	1	3	3
Theme 3	4	3	1	1	3	1	1	4	1	1	1	1	1	1	1	1	2	1	1	1	4	1	1	1	1	1	1	1
Theme 4	4	4	1	1	1	3	1	4	1	1	2	1	2	1	1	4	1	1	4	1	4	1	2	1	1	1	1	1
Theme 5	4	1	3	2	4	2	2	3	1	2	3	1	2	3	1	2	2	4	4	1	4	1	2	2	4	1	2	3

The analysis reveals that the "Foundational literacies" focuses "literacy" as the main target competency. "Numeracy" and "physical/health literacy" are included to a similar extent, while the emphasis of "ICT literacy/digital literacy" and "data literacy" is limited. In the "Skills, Attitudes & Values for 2030" component, "problem-solving" appears as the main target competency. "Self-regulation/self-control" and "persistence/resilience" are absent. However, in the "Transformative Competencies and Competency Development for 2030" component, there is a stronger emphasis on competencies such as "reconciling dilemmas and tensions" and "action", with "taking responsibility" being included, albeit to a limited extent.

TCM heat map of 2022 CECCS

Concerning "Foundational literacies", it is notable that the 2022 CECCS has enhanced "ICT literacy/digital literacy" and "data literacy" (Table 9). Concerning "Skills, Attitudes & Values for 2030", the TCM map shows the inclusion of "self-regulation/self-control" and "persistence/resilience" within the 2022 CECCS are improved, which were absent in 2011 CECCS. In terms of "Key concepts", the 2022 CECCS demonstrates a strong enhancement compared to the limited inclusion in the 2011 CECCS. The "Transformative Competencies and Competency Development for 2030" component is also reinforced more thoroughly in the 2022 CECCS. Notably, both "creating new value" and "reflection" are involved, which were insufficient in the 2011 CECCS. Moreover, "taking responsibility" is enhanced. Concerning "Compound competencies for 2030," the results show that "computational thinking/coding/programming" is suggested in the 2022 CECCS, whereas it was absent in the 2011 CECCS. Furthermore, there is a strong improvement regarding "media literacy" and "literacy for sustainable development". "Financial literacy" and "entrepreneurship" also demonstrate a higher inclusion in the 2022 CECCS compared to the 2011 CECCS.

Summary of TCM heat map regarding 2011 and 2022 CECCS

In summary, the progression of competencies over time is evident through the two TCM heat maps (Tables 8 and 9). Overall, the 2011 CECCS TCM heat map include "Foundational literacies" and "Transformative Competencies and Competency Development for 2030" as the main target competencies. Specifically, "literacy" and "action" receive significant emphasis among the twenty-eight competencies. "Compound competencies for 2030" is insufficient.

In the 2022 CECCS, there is notable inclusion of competencies. There are improvements in requirements concerning "Compound competencies for 2030" in general, and "media literacy" as well as "literacy for sustainable development" in particular. In addition, there are improvements in "Foundational literacies". For example, "ICT literacy/digital literacy" is involved by encouraging students to effectively use information and communication technologies both inside and outside the school environment, which was limited in the 2011 CECCS.

Learning area focus

According to the CCM subject coding framework (see Table 3), coding units are examined to identify the subject codes suggested by OECD (2019a). By generating Level 4 and Level 3 competencies (see Table 2), it aims to explore the distribution of the OECD competencies in each learning area (NSC1-NSC7) (Table 10). The results showed that NSC1, NSC3, NSC5, and NSC7 are widely expanded in the 2022 CECCS. In 2022 CECCS, students are encouraged to develop problem-solving methods (M) to enhance their engagement in practice (P) in daily life (Table 5). This has led to an improvement in NSC1 compared to the 2011 CECCS.

Further data showed that the experiments in the 2022 CECCS incorporated more interdisciplinary tasks and activities. Examples include *"conducting interdisciplinary*

Table 9 TCM heat map of 2022 CECCS

2022	Foundational Literacies					Skills, Attitudes & Values for 2030									Key Concepts		Transformative Competencies and Competency Development for 2030						Compound competencies for 2030					
	Literacy	Numeracy	ICT literacy /Digital literacy	Data Literacy	Physical/health literacy	Cooperation/ collaboration	Critical thinking	Problem solving	Self-regulation/ self-control	Empathy	Respect	Persistence/resilience	Trust	Learning to Learn	Student Agency	Co-agency	Creating new value	Taking responsibility	Reconciling dilemmas and tensions	Anticipation	Action	Reflection	Global Competency	Media literacy	Literacy for Sustainable Development	Computational thinking /coding/programming	Financial literacy	Entrepreneurship
Theme 1	4	4	3	4	4	4	4	4	4	3	4	4	4	4	4	4	4	4	4	4	4	4	3	4	3	2	1	3
Theme 2	4	4	4	4	3	3	4	4	1	3	4	2	4	4	4	4	4	4	4	4	4	4	4	4	4	1	4	3
Theme 3	4	4	4	4	1	2	1	3	1	3	4	2	3	4	3	3	3	1	1	4	4	1	3	4	1	1	1	1
Theme 4	4	4	4	3	4	4	3	4	1	1	4	1	3	4	4	4	3	4	4	3	4	2	3	4	4	4	3	3
Theme 5	4	1	4	1	4	4	4	4	3	3	4	4	4	4	3	4	4	4	4	4	4	4	3	4	4	1	2	3

Table 10 CMM-relevant items of the main objective (Level 4) and sub-objective (Level 3) in 2011 and 2022 CECCS

Categories	Year	Foundational Literacies	Skills, Attitudes & Values for 2030	Key Concepts	Transformative Competencies and Competency Development for 2030	Compound competencies for 2030	Sum
NSC1	2011	37 (13%)	1 (0%)	0 (0%)	6 (2%)	2 (1%)	46
	2022	69 (15%)	61 (13%)	3 (1%)	38 (8%)	12 (3%)	183
NSC2	2011	11 (4%)	1 (0%)	1 (0%)	2 (1%)	3 (1%)	18
	2022	12 (3%)	25 (5%)	4 (1%)	26 (6%)	4 (1%)	71
NSC3	2011	18 (6%)	28 (10%)	13 (5%)	33 (12%)	0 (0%)	92
	2022	51 (11%)	74 (16%)	9 (2%)	120 (26%)	20 (4%)	274
NSC4	2011	23 (8%)	6 (2%)	0 (0%)	16 (6%)	6 (2%)	51
	2022	23 (5%)	22 (5%)	5 (1%)	62 (14%)	46 (10%)	158
NSC5	2011	6 (2%)	6 (2%)	0 (0%)	1 (0%)	1 (0%)	14
	2022	13 (3%)	57 (12%)	13 (3%)	32 (7%)	25 (5%)	140
NSC6	2011	0 (0%)	0 (0%)	0 (0%)	0 (0%)	3 (1%)	3
	2022	2 (0%)	8 (2%)	2 (0%)	9 (2%)	9 (2%)	30
NSC7	2011	3 (1%)	0 (0%)	0 (0%)	2 (1%)	2 (1%)	7
	2022	16 (3%)	30 (7%)	3 (1%)	76 (17%)	80 (17%)	205

project-based learning (PBL) activities and designing low carbon action plans based on carbon neutral commitment" (page 21); *"Design and make oxygenators based on specific needs" (page 32)*, among others. Basic experiments such as carbon dioxide or oxygen generation in laboratories are more focused on knowledge and skill development, leaving limited room for the development of students' subject competency. However, the inclusion of interdisciplinary project-based learning tasks requiring students' interdisciplinary knowledge and experience in science, technology, engineering, and mathematics (STEM) represents a significant improvement in the new curriculum standards. The enhancement of PBL tasks and activities helps to explain the increased presence of NSC3 in (Table 10).

Regarding NSC5, the analysis reveals a recognition and appreciation for the efforts and contributions of scientists. Interdisciplinary PBL tasks and activities encourage students to think and solve problems like a scientist. The application of chemistry in real-world contexts and its connection to society are emphasized. For example, *"learn and appreciate the wisdom and method used by chemists to understand the nature of science through well-known experiments in the development of chemistry" (page 14, 2022 CECCS)*. These representations were limited in the 2011 CECCS, which helps to understand why NSC5 in the 2022 CECCS exhibits a higher degree of inclusion.

Moreover, the concepts of sustainable development, green chemistry, and global competency were widely expanded in the 2022 CECCS. For example, there is an emphasis on *"establishing a sustainable development philosophy of peaceful coexistence between man and nature" (page 31, 2022 CECCS)*. The enhancement of compound competency may explain why NSC7 tends to be more prominent in the new version compared to the old one.

The Analysis of Theme 4: Chemical changes of substance

The 2022 CECCS demonstrates a meaningful improvement compared to the 2011 CECCS. Of particular relevance, the 2022 CECCS was edited by incorporating the BCMAP model (Fig. 1). Each learning theme of 2022 CECCS is structured by the multidimensional BCMAP model. In addition, every learning theme reflects the integrated meaning and requirements of core competencies through B (Big Idea). By combining B (Big Idea) and C (Core Knowledge), the content and requisites of the theme are conveyed in terms of chemical concepts. The requirements for scientific thinking are achieved through "Methods" (M). Additionally, the specific learning requirements for scientific attitudes and responsibilities are addressed through "Applying and Attitude" (A). Furthermore, the requirements for scientific inquiry and practice-based core competencies are clarified in P (Practice). The interconnection between these four dimensions is symbolized by the line in the diagram (Fig. 1). This model aims to foster students to learn core knowledge, develop research methods, form basic attitude, and construct a broader understanding of each theme.

This study further analyzed the curriculum content Theme 4 "chemical changes of substance" to illustrate how the BCMAP model is employed. Table 11 provides a clear demonstration of how the five dimensions of the BCMAP model structured and functionalized the curriculum content. Of particular relevance, Theme 4 focuses on the Big idea (B) of understanding the changes and

Table 11 The illustration of Theme 4's BCMAP

Key elements	Content	Example
Big idea (B)	4.1 Changes and transformations of substance	Recognize that substance changes accompany the process of energy change, and the transformation of substances can be achieved through chemical reactions under certain conditions; Recognize quantitative correlations exist between substances in chemical reactions and develop an initial cognition of transformation (2022 CECCS, page 26)
Core knowledge (C)	4.2 Chemical Reactions and the Law of Conservation of Mass	Investigate the conditions of combustion (2022 CECCS, page 27)
Method (M)	4.3 Ideas and Methods for recognizing chemical reactions	Develop initial ideas about using chemical reactions to investigate substances' properties, compositions, preparation, and testing issues in a real context (2022 CECCS, page 27)
Applying and Attitude (A)	4.4 The application value of chemical reactions and reasonable regulation	Establish resource recycling and green environmental awareness (2022 CECCS, page 28)
Practice (P)	4.5 Students' compulsory experiments and practical activities	Inter-disciplinary practical work (2022 CECCS, page 28)

transformations of substance. Students are expected to develop corresponding problem-solving Methods (M) (see 4.3) and Applying and Attitude (A) (see 4.4) based on their Core knowledge (C) (see 4.2) to engage Practice (P) (see 4.5) within real-life contexts.

Moreover, in the 2022 CECCS, curriculum contents are represented under the "content requirement" session through the BCMAP-oriented approach. This approach emphasizes the core knowledge, skills, and attitudes that students are expected to acquire. Additionally, the "academic requirements", "teaching strategy suggestion", "contexts suggestion", and "activity suggestion" sections serve as scaffolding tools to support students in achieving the BCMAP-oriented core competencies.

Regarding the distribution of the five OECD competencies within theme 4, the results indicate that theme 4 is more prominently aligned with "Transformative competencies and competency development for 2030". It is closely followed by "Foundational literacies" and "Skills, attitudes & values". The presence of "Compound competencies for 2030" is also suggested within this theme. However, "Key concepts" exhibit a limited level of inclusion. One possible explanation for this difference is that Theme 4 primarily focuses on fundamental knowledge. Therefore, knowledge, competency, and attitudes are highly included in this theme. This explains why most coding units align with "Foundational literacies", "Skills, attitudes & values", as well as "Transformative competencies and competency development for 2030" (Fig. 2).

Results and discussion

This study revealed the similarities and differences in the curriculum content structure between the 2011 and 2022 Compulsory Education Chemistry Curriculum Standards (CECCS). It concentrated on identifying the representation levels of CECCS compared to the curriculum

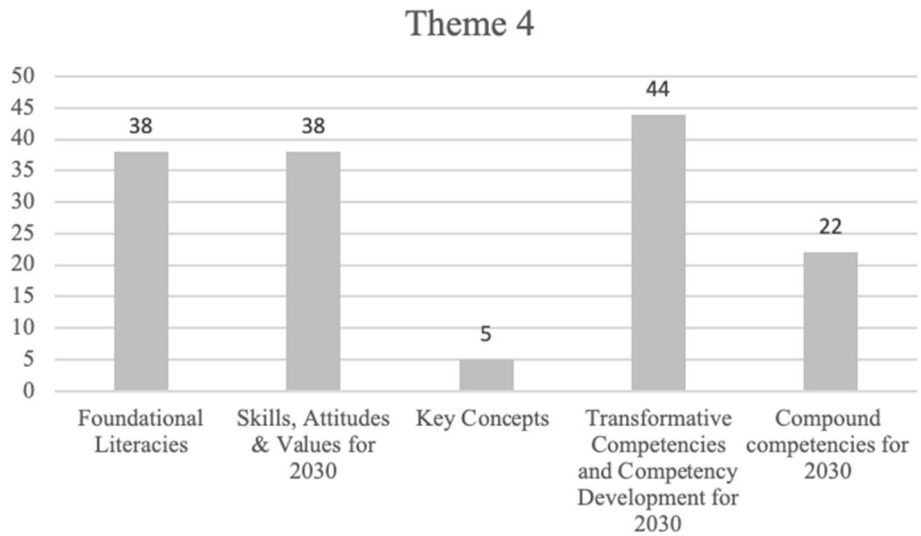

Fig. 2 OECD competency distribution

content mapping (CCM) suggested by OECD (2019a), with specific attention given to the five themes of the Chinese Compulsory Education Chemistry Curriculum Standards. Based on this, a systematic four-step coding and analyzing approach was developed, resulting in the creation of four comprehensive heat maps. Two CCM heat maps and two TCM heat maps were used to understand the representation levels of the 2011 and 2022 CECCS with the OECD competencies. Furthermore, a BCMAP model (Wang, 2022) highlighted the similarities and inherent differences in content construction across different branches.

Overall, the content framework of the two CECCS aligns well with the OECD's CCM competencies, with the 2022 CECCS showing a more advanced level. The 2011 CECCS emphasized three main domains: knowledge and skill, process and method, and attitudes and values. It included aspects of "Skills, attitudes & values" and "Foundational literacies", with some focus on "Transformative competencies and competency development for 2030". Additionally, ideas related to science, technology, society, and environment (STSE) were suggested, contributing to the development of students' "Compound competencies for 2030". However, "Foundational literacies" showed low requirements for subject competency. For example, concepts like "empathy" and "persistence/resilience" were considered irrelevant to chemistry teaching and learning, and thus were absent in the 2011 CECCS. In addition, there was a heavier emphasis on calculation skills compared to real-life problem-solving or data interpretation abilities. Of particular relevance, further data of the CMM heat maps and (Table10) revealed that concepts such as chemistry properties in daily life context (NSC1), chemical safety (NSC2), scientists' work (NSC5), scientific ethos, ethic ideology, laws, and regulations (NSC6) were limited or absent in the 2011 CECCS.

However, the data indicated that the 2022 CECCS filled these gaps through the incorporation of a BCMAP-structured and competency-oriented curriculum. Concerning "Foundational literacies", the 2022 CECCS helped to promote students' core competency by integrating problem-solving skills within real-life research contexts. Notably, interdisciplinary practiced appeared in the 2022 CECCS, which is a significant improvement as interdisciplinary activity engages students' learning in a broader way (Zowada et al., 2018). The 2022 CECCS required that at least 10% of curricula should be applied for interdisciplinary investigation. Students are encouraged to apply their knowledge in solving problems through project-based activities, practical work, and other approaches.

Remarkably, further data demonstrated that 2022 CECCS emphasized higher-level of competency requirement regarding chemical safety (related to NSC2), practical work (related to NSC3), cognitive knowledge and skills (related to NSC5), global citizenship, and sustainable development education (related to NSC7). The 2022 CECCS encourages students to think like scientists and solve problems through project-based learning, which helps establish a meaningful connection between students' knowledge/skills and the vocational domain. This aligns with the idea proposed by Stuckey et al., (2013a, 2013b).

Overall, the new curriculum attempted to reflect the curriculum improvement of Chinese curriculum reform over the past ten years. It updated the curriculum content to reflect advancements in science, technology, economic, and societal development from a global education perspective. One notable characteristic was the use of the BCMAP model to scaffold core knowledge, methods, applying and attitudes, and practices. This model emphasized the need for a multidimensional curriculum instead of a fundamental knowledge-oriented curriculum. Additionally, regarding the 2022 CECCS, specific sessions on "academic requirements", "teaching strategy suggestion", "contexts suggestion", and "activity suggestion" were included to ensure the development of core competencies.

Conclusion

It is notable that curriculum standards convey the intended curriculum and play an important role in facilitating students' competency development. The compulsory chemistry curriculum provides enlightenment follow-up education by forming a bridge between primary science education and upper secondary science education. It serves as a foundation course to prepare students to become responsible individuals in society (Wang, 2022). Moreover, it outlines the general characteristics and requirements for secondary school chemistry education.

This study provides evidence-based instructional requirements by 2011 and 2022 CECCS. A comparison between them reveals that the curriculum standard is shifting towards broader and higher inclusive competencies. Specifically, the 2022 CECCS places emphasis on many of the twenty-eight competencies, whereas the 2011 CECCS prioritizes "Foundational literacies" and "Transformative Competencies and Competency Development for 2030" as the most significant ones. Furthermore, there has been a development in the competencies related to practical application in real-life situations, such as engaging interdisciplinary tasks and activities, emulating scientists, and addressing global environmental issues, among others.

In addition, Theme 4 analyzed the scaffolding of the new 2022 CECCS by demonstrating a multidimensional BCMAP model. Firstly, it identifies how core competencies are reflected in the competency-oriented curriculum

content and guides curriculum implementation. Secondly, it enriches the understanding of CCM and TCM by offering additional evidence to comprehensively understand how knowledge is intended to be received with competencies as well as values.

Nevertheless, it is important to note that there may be a discrepancy between the curriculum standards, the curriculum prescribed in textbooks, and the actual curriculum implemented by teachers in schools (Van Den Akker, 1998). Future efforts might be paid to evaluate effective resources that align with the standards for diverse learning needs. This would require a collaborative effort involving policymakers, educators, and practitioners to develop curriculum materials and teaching strategies together (Eilks & Hofstein, 2017).

Limitations and further work

Drawing on international curriculum research and projects, and combining China's local educational experience, the Compulsory Education Chemistry Curriculum Standards (CECCS) curriculum reform promotes the development of core competencies into a multidimensional BCMAP model to meet students' needs of the future. This study offers insights into the evolution of CECCS over time and contributes to identifying additional areas for evaluating a more inclusive global education system. It provides evidence-based experiences and reflections to evaluate how a curriculum focused on core competencies can effectively guide its implementation. It also provides guidance for in-service teachers by offering "academic requirements," "teaching strategy suggestions," "contextual suggestions," and "activity suggestions" for implementing the CECCS.

However, it is unable to make any predictions about how the competencies outlined in the curriculum standards are being implemented in different educational institutions. This would be an interesting starting point for further research efforts. Through examining curriculum standards' impact on diverse student populations, educators can advocate for necessary resources, policies, and instructional strategies to ensure equitable implementation of instruction.

Abbreviations

OECD	Organization for Economic Co-operation and Development
CECCS	Compulsory Education Chemistry Curriculum Standards
CCM	Curriculum Content Mapping
TCM	Theme Content Mapping
NSC	National Science Chemistry
PBL	Project-based learning

Acknowledgements

We are grateful for the support afforded to the research by Beijing Normal University.

Authors' contributions

Conceptualization, X.G.C., X. S. and L. W.; methodology, X. S. and L. W.; validation, X.G.C. and X. S.; formal analysis, X.G.C. and X. S.; writing original draft, X.G.C.; writing—review and editing, X.G.C., L. W. and R. W.; supervision and project administration, L. W. and R. W. All authors have read and approved the manuscript.

Funding

International joint research project of Faculty of Education, Beijing Normal University (ICER201802).

Availability of data and materials

The datasets analyzed during the current study are potentially to be used in the author's dissertation, they are available from the corresponding author on reasonable request.

Declarations

Ethics approval and consent to participate

Data were collected following national data protection laws. This study does not involve animal, plant or human data.

Consent for publication

Not applicable.

Competing interests

The authors declare no conflict of interest.

Received: 4 July 2023 Accepted: 26 November 2023
Published online: 03 January 2024

References

Belova, N., & Eilks, I. (2015). Research and innovation on learning with and about advertising in science education. In N. L. Yates (ed.). *New developments in science education research* (pp. 29–50). Hauppauge: Nova.

Brassler, M., & Dettmers, J. (2017). How to enhance interdisciplinary competence—Interdisciplinary problem-based learning versus interdisciplinary project-based learning. *Interdisciplinary Journal of Problem-Based Learning, 11*(2), 12.

Chen, X., Goes, L. F., Treagust, D. F., & Eilks, I. (2019). An analysis of the visual representation of redox reactions in secondary chemistry textbooks from different Chinese communities. *Education Sciences, 9*(1), 42.

Chen, X., Chiu, M. H., & Eilks, I. (2018). An analysis of the orientation and emphasis of intended grade-10 chemistry curricula as represented in textbooks from different Chinese communities. *EURASIA Journal of Mathematics, Science and Technology Education, 15*(2), em1663.

Eilks, I., & Hofstein, A. (2017). Curriculum development in science education. In B. Akpan & K. S. Taber (Eds.), *Science education: An international comprehensive course companion* (pp. 169–181). Rotterdam: Sense.

Erduran, S., & Dagher, Z. R. (2014). Regaining focus in irish junior cycle science: potential new directions for curriculum and assessment on Nature of Science. *Irish Educational Studies, 33*, 335–350.

Gervedink Nijhuis, C. J., Pieters, J. M., & Voogt, J. M. (2013). Influence of culture on curriculum development in Ghana: an undervalued factor? *Journal of Curriculum Studies, 45*(2), 225–250.

Khaddoor, R., Al-Amoush, S., & Eilks, I. (2017). A comparative analysis of the intended curriculum and its presentation in 10th-grade chemistry textbooks from seven Arabic countries. *Chemistry Education Research and Practice, 18*(2), 375–385.

Kokotsaki, D., Menzies, V., & Wiggins, A. (2016). Project-based learning: A review of the literature. *Improving Schools, 19*(3), 267–277.

Ma, H., Fulmer, G. W., Liang, L. L., Chen, X., Li, X., & Li, Y. (2013). An Alignment Analysis of Junior High School Chemistry Curriculum Standards and City-Wide Exit Exams in China. In M. H. Chiu, H. L. Tuan, H. K. Wu, J. W. Lin, & C. C. Chou (Eds.), *Chemistry Education and Sustainability in the Global Age*. Dordrecht: Springer. https://doi.org/10.1007/978-94-007-4860-6_14

Meng, H. W. (2018). OECD learning framework 2030. *Journal of Open Learning, 23*(3), 9–12. (in Chinese).
Ministry of Education. (2019). The Ministry of Education launches compulsory education curriculum revision. Available at: http://www.moe.gov.cn/jyb_zzjg/huodong/ 201901/t20190103_365862. html. (Accessed 17 Sept 2022)
Ministry of Education. (2011). Ministry of Education on the issuance of compulsory education curriculum standards (2011 Edition). http://www.moe.gov.cn/srcsite/A26/s8001/201112/t201112twenty-eight_167340.html. (Accessed 17 Sept 2022)
Ministry of Education. (2022). Ministry of Education on the issuance of compulsory education curriculum standards (2022 Edition). http://www.moe.gov.cn/srcsite/A26/s8001/202204/t20220420_619921.html. (Accessed 17 Sept 2022)
Nasir, M. (2021). Curriculum development and accreditation standards in the traditional Islamic schools in Indonesia. *Journal of Curriculum Studies Research, 3*(2), 37–56.
Organization for Economic Co-operation and Development (OCED) (2018). The future of education and skills: Education 2030. Available at: E2030 Position Paper (05.04.2018).pdf (oecd.org). (Accessed 17 Sept 2022)
Organization for Economic Co-operation and Development (OCED) (2019a). Education 2030 Curriculum Content Mapping: An Analysis of the Netherlands Curriculum Proposal. https://t4.oecd.org/education/2030-project/contact/E2030_CCM_analysis_NLD_curriculum_proposal.pdf (Accessed 17 Dec 2022)
Organization for Economic Co-operation and Development (OCED) (2019b). The OECD learning compass 2030. https://www.oecd.org/education/2030-project/teaching-and-learning/learning/ (Accessed 17 Nov 2022)
Stuckey, M., Hofstein, A., Mamlok-Naaman, R., & Eilks, I. (2013a). The meaning of 'relevance' in science education and its implications for the science curriculum. *Studies in Science Education, 49*, 1–34.
Van den Akker, J. (1998). The science curriculum: Between ideals and outcomes. In B. Fraser & K. Tobin (Eds.), *International handbook of science education* (pp. 421–447). Kluwer.
Vojíř, K., & Rusek, M. (2019). Science education textbook research trends: a systematic literature review. *International Journal of Science Education, 41*(11), 1496–1516.
Wang, L. (2016). Exploring performance and intrinsic composition of disciplinary competency—based on the multi-integrative model of 'learning-applying -innovating.' *Educational Research, 37*(9), 83–92.
Wang, L. (2022). Unify the multidimensional curriculum content based on the big ideas and externalize the requirements of the core competency development of learning themes: the focus of the revision of the curriculum content of compulsory education curriculum standards: Chemistry. *Curriculum, Teaching Material, and Method, 42*(8), 47–54. (in Chinese).
Wang, L., Shao, X., Zheng, C. L., Hu, J. H., & Wei, R. (2021). Compulsory curriculum content map analysis based on OECD Learning Framework 2030. *Basic Education Curriculum, 2021*(5), 16–24. (in Chinese).
Wang, L., Wang, Q., Kong, S., Hu, J., & Chen, X. (2022). Subject competency framework in fostering high-end lesson study–a case of teaching "properties of iron salts" unit in a senior high school. International Journal for Lesson & Learning Studies, (ahead-of-print).
Wei, B., & Ou, Y. (2019). A comparative analysis of junior high school science curriculum standards in Mainland China, Taiwan, Hong Kong, and Macao: based on revised Bloom's taxonomy. *International Journal of Science and Mathematics Education, 17*, 1459–1474.
Zhang, T., Cai, Q. P., & Ma, H. Q. (2019). An empirical study on policy content analysis method based on policy text computing: take internet tenting bicycles as an example. *Journal of Information Resources Management, 9*(1), 66–76. (in Chinese).
Zidny, R., Sjöström, J., & Eilks, I. (2020). A multi-perspective reflection on how indigenous knowledge and related ideas can improve science education for sustainability. *Science & Education, 29*, 145–185.
Zowada, C., Gulacar, O., & Eilks, I. (2018). Incorporating a web-based hydraulic fracturing module in general chemistry as a socio-scientific issue that engages students. *Journal of Chemical Education, 95*(4), 553–559.

Publisher's Note