Disciplinary and Interdisciplinary Science Education Research

RESEARCH Open Access

Curriculum content mapping of the Chinese National Biology Curriculum Standards for middle school: an analysis from the OECD Education 2030 perspective

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Abstract

Curriculum standards are a critical component of a nation's educational system and directly impact talent development and overall national development. Most studies on curriculum standards focus on a single competency. This study aims to understand the extent to which the competencies outlined in the OECD 2030-oriented learning framework are reflected in China's compulsory education biology curriculum as a whole and within individual content subjects. In this study, we conducted a content analysis of China's *National Biology Curriculum Standards (Grades 7–9)*. The result shows that the standards cover 20 of the 28 competencies, focusing on foundational literacies, transformative competencies and competency development. We found that certain competencies, such as Action, Literacy, and Problem-solving, were emphasized across content subjects, while other competencies were uniquely emphasized within specific content subjects. This study provides a comprehensive view of China's *National Biology Curriculum Standards* (Grades 7–9) from the perspective of future literacy development and can inform efforts to reform the curriculum.

Keywords Curriculum content mapping, Curriculum standard, OECD 2030, Biology curriculum

Introduction

As globalization and societal changes accelerate, governments worldwide prioritize education to cultivate citizens who can adapt to the changing society. Education systems are therefore under pressure to better prepare their students for the "future" and for the "real world" (OECD, 2019b). In 2015, the Organization for Economic Cooperation and Development (OECD) launched the "Future of Education and Skills 2030" project to establish key competency goals for 2030. Based on the 2030-oriented learning framework, the OECD has developed the first international comparative analysis tool on curricula, Curriculum Content Mapping (CCM), to meet the multiple needs of the nation, society, and individual development. In response to these trends, China released its *National Biology Curriculum Standards (Grades 7–9)* (NBCS (7–9)) in 2022. Whether curriculum standards can meet the requirements of future-oriented talent training and how to further optimize the construction of curriculum in the new era are common challenges faced by all countries in designing and implementing future-oriented curriculum. The competencies in the OECD 2030-oriented learning framework can point out the direction for the development of education in countries. Curriculum standards stipulate the goal of education, the core of which is to cultivate future citizens. Consequently, the

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CCM analysis based on the competencies in the OECD 2030-oriented learning framework can provide a comprehensive picture of the extent to which curriculum design can facilitate the cultivation of future-ready citizens and thus furnish valuable insights for the refinement and enhancement of curriculum standards. Furthermore, the findings of the study can also provide a reference for the design and revision of curriculum standards in other countries or regions. Against this context, this study aims to review the newly released curriculum standards for self-reflection while providing learnable recommendations that promote key competencies in students for the future.

Competencies for the future

Education systems worldwide are facing unprecedented challenges due to the rapid development of society. Numerous nations, international organizations, and economies have conducted relevant research and developed future-oriented competency frameworks with various elements to better prepare students for an uncertain future. The OECD introduced the "Learning Compass 2030" which describes the competencies students will need to flourish in the future and help create better lives for both individual and societal well-being, including core foundations, transformative competencies, knowledge, skills, attitudes, and values, as well as a cycle of anticipation, action, and reflection (OECD, 2019a). The Partnership for 21st Century Learning (P21) (2019) developed the "Framework for 21st Century Learning," which encompasses three areas of competencies: learning and innovation skills, information, media, and technology skills, and life and career skills. The European Commission Directorate-General for Education, Youth, Sport and Culture (2019) identified eight key competencies in its "Recommendation on Key Competencies for Lifelong Learning," including literacy competence, multilingual competence, mathematical competence, and competence in science, technology, and engineering, among others. The United Nations Educational, Scientific, and Cultural Organization (UNESCO) Asia and Pacific Regional Bureau for Education (2015) published a report on developing a framework for "transversal competencies," which includes five major areas: critical and innovative thinking, interpersonal skills, intrapersonal skills, global citizenship, and media and information literacy. China's Key Competencies Research Group (2016) identified six key competencies for Chinese students: humanistic heritage, scientific spirit, learning to learn, healthy life, responsibility, practice, and innovation.

By analyzing and comparing the specific connotations of these frameworks, we can identify commonalities among them. Table 1 presents the result of merging competencies with similar meanings, valued by the five frameworks and classified into five different orientations. It is important to note that in each framework, the competencies do not exist independently; rather, they intersect and overlap, with aspects essential to one domain supporting competence in another.

Curriculum standards attach importance to the development of students' competencies

Curriculum standards are national policy documents that outline a country's expectations and vision for the development of its future citizens and serve as an authoritative, directive, and programmatic guide for curriculum development. In some countries, biology curriculum standards are set separately, while in others, science curriculum standards that combine physical science, life science, and earth and space science are used. The structure of national curriculum standards varies, but they generally include elements such as curriculum philosophy, curriculum objectives, curriculum content, and academic assessment (NGSS Lead States, 2013; Ministry of Education, Singapore (MoES), 2013; Department for Education (DfE), 2015; Ministry of Education (MoE), 2022a, b, c; Australian Curriculum Assessment to Reporting Authority (ACARA), 2018).

Curriculum standards in all countries outline requirements for student competencies. The Next Generation Science Standards (NGSS) identifies these objectives across three dimensions: science and

Table 1 Common future competencies in five frameworks

Orientation	Future competencies
Basic Disciplines	Literacy competency, mathematical competency, science and technology competency, physical and mental health
Emerging Skills	Digital literacy, information literacy, media literacy, environmental literacy, financial and business literacy
Higher order cognition	Critical thinking, creativity and innovation, problem-solving skills, learning to learn competency
Intra-individual	Self-awareness, self-regulation, reflective thinking, curiosity, and inquiry skills
Interpersonal & Social	Communication and collaboration, global awareness and open mindset, cross-cultural skills and international understanding, civic responsibility and social engagement, compassion and tolerance, flexibility and adaptability

engineering practices, disciplinary core ideas, and crosscutting concepts, with "performance expectations" that specify the required competencies for students (NGSS Lead States, 2013). The British Science Programmes of Study outline overall competency requirements in the "aims" section and provide achievement targets for student competencies under each "key stage" (Department for Education (DfE), 2015). The Australian science curriculum standard also presents general requirements for student competencies in the "aims" section and details students' competency performance in the "content and achievement sequences" section (Australian Curriculum Assessment to Reporting Authority (ACARA), 2018). In Singapore's Science Syllabus, the "learning results" section of the "curriculum contents" reflects the requirements for student competency achievement (Ministry of Education, Singapore (MoES), 2013). NBCS (7–9) elaborates on four key competencies of the ideas of life, scientific thinking, inquiry and practice, and attitudes and responsibilities in the "curriculum objectives." and specifies requirements for student competency performance in the "academic requirements" section. This demonstrates that developing student competencies is a widely acknowledged educational goal that is often highlighted in the various sections of curriculum standards across nations.

Methods for analyzing curriculum standards

Traditionally, the analysis of curriculum standards has served two primary purposes, to assess the quality of the standards and to compare the similarities and differences between or among sets of standards (Tran et al., 2016). Many studies on curriculum standards analysis have employed content analysis (Carr et al., 2012; Chen et al, 2021; Mostacedo-Marasovic et al., 2022; Wei et al., 2019; Zeng & Wang, 2021). For instance, Carr et al. (2012) used content analysis to compile and analyze the presence and scope of engineering in the K-12 STEM standards in all 50 U.S. states and provided a consensus of the big ideas found in the standards. Wei & Ou (2019) adopted revised Bloom's taxonomy as a framework for analyzing the middle school curriculum standards among four Chinese regions and compared their similarities and differences. The content analysis method, generally consisting of unitizing, sampling, recording/coding, reducing data to manageable representations, abductively inferring contextual phenomena, and narrating the answers to the research question (Krippendorff, 2019), follows the standards of the scientific method with systematic procedures that focus on objectivity-intersubjectivity, reliability, validity, generalizability and replicability (Neuendorf, 2017).

Some studies have conducted a lexical search or analyzed the word frequency of curriculum standards. For example, Merritt & Bowers (2020) used lexical analysis of NGSS documents to identify instances of observational methods suggested in scientific and engineering practices and ecology-related performance expectations, exploring where and how much students are encouraged to observe and investigate the natural world as they learn ecological concepts in NGSS. Luo (2021) analyzed the word frequency related to "evidence-based reasoning" in science curriculum standards from 27 countries or regions. Additionally, Some studies have adopted a direct comparison approach to provide suggestions for revising the standards. These comparisons typically consider similarities and differences in the rationale, expectation, learning area, or presentation of competencies within curriculum standards (Lee, 2017; Li & Xie, 2022; Tang & Liu, 2001; Zhang & Wei, 2012). This kind of comparison relies on the researcher's subjective judgment and ideas, which requires a high level of researcher literacy.

When considering different research methods, content analysis stands out as a relatively systematic and valid approach that allows for replication by other researchers (Krippendorff, 2019). However, it also involves some level of subjective interpretation, so the reliability and validity of its conclusions need to be ensured by strengthening the quality of the coding scheme and conducting training for coders (Neuendorf, 2017).

Analysis and research on competencies in curriculum standards

To enhance the effectiveness of curriculum standards, further develop student competencies, and meet the needs of the future society, many researchers both within and outside the country have analyzed competencies in curriculum standards(Zhang & Wei, 2012; Lee, 2017; Summer et al., 2019; Fu & Wang, 2019; Merritt & Bowers, 2020; Luo, 2021; Huang, 2021; Zeng & Wang, 2021). Table 2 presents the sorting results of this research.

It can be seen from the results that most of the studies focus on a single competency within the curriculum standards, rather than conducting a systematic analysis from an overall perspective. Additionally, the research on content subjects and competency requirements is often isolated, making it difficult to comprehensively understand the relationship between elements such as knowledge, skills, attitudes, and values. Thus, it is challenging to provide general suggestions for the preparation and revision of curriculum standards.

Therefore, there is a need to conduct a systematic analysis of curriculum standards from the perspective of the relationship between overall content subjects and competencies to explore how knowledge and skills can

Table 2 Different researchers' research on dimension in curriculum standards

Author	Years	Analysis dimension of curriculum standard
Zhang & Wei	2012	Scientific inquiry
Lee	2017	Scientific argument
Summers, Alameh, Brunner, Maddux, Wallon, & Abd-El-Khalick	2019	Nature of science
Fu & Wang	2019	Critical thinking
Merritt & Bowers	2020	Ecological literacy (observation-based ecology)
Luo	2021	Evidence-based reasoning
Huang	2021	Literacy for sustainable development
Zeng & Wang	2021	Science and engineering practice

be learned in an integrated manner and to better understand the relationship between subject content and competencies, and develop specific competencies within the appropriate content subjects. Such analysis can provide a reference for the revision and improvement of curriculum standards.

Reform of compulsory education biology curriculum standards in China

The revision of China's curriculum standards has gone through three stages since the 1950s. The first stage of the reform is primarily characterized by updates to the curriculum's content and changes to its conceptual framework. The *Full-time National Biology Curriculum Standards (Grade 7–9) (trial edition)* (2001) introduced the curriculum concepts of "facing all students", "improving biological competency", and "advocating inquiry learning", it also introduced the content of "scientific inquiry" for the first time, advocating research-based learning for students.

In the second stage, the curriculum standards supplemented and improved the characteristics of the curriculum and emphasized the transmission of key concepts. It highlighted the "scientific education" attribute of the biology curriculum and specifically described the teaching requirements of related concepts in the form of connotations or propositions (Ministry of Education (MoE), 2011; Liu, 2012).

In the third stage, the curriculum objectives and philosophy changed. The curriculum goal shifted from knowledge, ability, attitude, and values to a focus on the development of four dimensions of key competencies. It introduced a more systematic curriculum philosophy, emphasizing the connection and cohesion of different knowledge systems and the logic between learning themes. The curriculum standard also highlights interdisciplinary practice and students' ability to solve problems comprehensively (Ministry of Education (MoE), 2022a).

Previous research regarding curriculum content mapping

The OECD initiated the CCM exercise to help analyze the extent to which the curriculum develops competencies essential for future life and work, explore how knowledge is taught alongside skills, and better understand the relevance of particular skills, attitudes, and values to certain areas of learning. The exercise provides a tool and methodology for curriculum analysis, and the final mapping grid presenting the result is a two-dimensional matrix consisting of a competency framework and a content subject framework, with a 4-level scale labeled with different shades of color to indicate the extent to which a content subject supports and achieves a particular competency. The result of the analysis can provide concrete evidence for curriculum reform and insight into the curriculum redesign process.

Since the initiation of the CCM exercise, many countries, including China, have participated in the analysis of curriculum standards, indicating that the results have guiding significance for curriculum reform (OECD, 2020). In China, the main objects of analysis are the 2011 edition of curriculum standards (Cao et al., 2020; Wang et al., 2021a; Liao & Wang, 2021; Wang et al., 2021b; Ren & Wang, 2021). The available studies on these analyses have primarily focused on general analysis, competency analysis, and content subject analysis. The analysis of content subjects is analyzing the frequency and percentage of content subjects corresponding to the different levels of specific competencies (Liao & Wang, 2021) or analyzing the frequency of the five major types of competencies in content subjects in the standards (Wang et al., 2021b), without separately analyzing the specific types of competencies embodied in each content subject and the degree of embodiment.

In addition, the content subjects identified by the OECD include biological concepts, scientific inquiry, safe practices, the nature of science, ethics, and

concepts related to global citizenship and education for sustainable development. The Chinese biology curriculum standards are divided into topics based on subject areas, such as structural levels of organisms and diversity of organisms. To better align with the presentation of Chinese biology curriculum standards, this study aims to analyze the newly published NBCS (7–9) in 2022 using the biology subject areas as the basis for the division of content subjects. This will help explore the relevance of specific competencies in developing future competencies in different areas of biology subjects at a more micro level.

Therefore, this study aims to address the following two research questions: (1) What competencies does the NBCS (7–9) cultivate for students in each content subject? (2) To what extent are these competencies expected to be attained by students based on the NBCS (7–9)?

Method

Select biology curriculum document and targeted content

This study selected NBCS (7–9) as the primary analytic document, the interpretation of curriculum standards and textbooks of people's education press as supporting materials. The above-mentioned supporting materials will be used as analysis objects when the relevant competencies are absent from NBCS (7–9). The content of the curriculum standard mainly includes the preface, philosophy, rationale, expectation, and learning area of the curriculum, study quality, curriculum implementation, and the appendix.

The preface section of the curriculum standards outlines the guiding philosophy, principles of revision, and major changes to the standards. The philosophy is mainly concerned with the overall design of the curriculum, which is a macro-level design idea. The rationale section describes the course's attributes and its position in the overall curriculum system. The expectation section clarifies the connotation of the four core competencies of ideas of life, scientific thinking, inquiry and practice, and attitude and responsibility, as well as the requirements for students upon completing the middle school biology curriculum. The content part of the curriculum is the core component of the curriculum standards, including seven learning themes and nine big ideas. The curriculum standards present specific requirements for learning themes, which are divided into four parts: general description, content requirements, academic requirements, and teaching tips. The academic quality section uses key competencies as the main dimensions and outlines the specific performance characteristics of students' academic achievement. The curriculum implementation section provides meso-level suggestions for implementation, including teaching suggestions, assessment suggestions, requirements for the development of teaching materials, development and utilization of curriculum resources, research on teaching, and teacher training suggestions. The appendix provides operational cases for reference on how to implement the requirements of the curriculum in teaching, including six teaching cases and one evaluation case.

Curriculum content mapping analytical framework

The analysis of the curriculum content mapping includes three main aspects, which are content subject, competency system, and criteria for determining competency levels.

Content subject

In terms of content areas, this study combined the content areas of biology to refine and form seven content subjects (Table 3), including the levels of biological organization, biodiversity, biology, environment, etc.

Competency system

The competency system is based on the competencies classification of OECD's Education 2030 Curriculum Content Mapping project. There are twenty-eight competencies in total, and these competencies have been grouped as "Foundational Literacies," "Skills, Attitudes, and Values," "Key Concepts," "Transformative Competencies and Competency Development," and "Compound Competencies". Table 4 shows the composition of the competency system.

Criteria for determining competency levels

Different content subjects have different requirements for competencies. According to the degree of embodiment and expectation to be attained by students, the competency can be divided into four levels (see Table 5).

Table 3 Content subject of biology

Content codes	Content subject
CSB1	The levels of biological organization
CSB2	Biodiversity
CSB3	Biology and environment
CSB4	Reproduction and development biology
CSB5	Life processes
CSB6	Genetics and evolution
CSB7	Biotechnology and bioethics

Data collection and analysis

Text coding

The coding process consists of three main steps. In the first step, the sentences in the NBCS (7–9) or supporting materials that can independently reflect the semantics are looked up to determine which content subject the relevant text belongs to (see Table 3). In the second step, based on the clarification of the basic characteristics and connotations of each specific competency, it is determined which competency is reflected in the items coded in the first step (see Table 4). In the third step, the text is coded according to the criteria for evaluating the level of competency (see Table 5). The competency level assigned to each content subject is determined by selecting the highest value of the competency level found within the items included under that specific content subject.

There provide an analytic case for coding (see Table 6). The content subject was categorized as "CSB1 The levels of biological organization" because it was linked to structure and function at the cellular level. Competency was coded as "Literacy" because this item required students to use and engage with biology-specific texts such as "diagrams or models". The competency level is coded as "3" because this item is in the academic requirements section of NBCS (7–9) and is stated as a sub-target.

Table 4 Competencies system (OECD, 2019a, b)

Competency dimension	Descriptions
Foundational Literacies	The competencies that serve as foundations for advanced learning, include literacy, numeracy, ICT literacy/digital literacy, data literacy, and physical/health literacy
Skills, Attitudes, and Values	The specific skills, attitudes, and values that students require to flourish and shape the world, include critical thinking, problem-solving, cooperation/collaboration, self-regulation/self-control, empathy, persistence/resilience, respect, trust, and learning to learn
Key concepts	The capacity and propensity to take purposeful initiative with the influence of teachers, peers, families and communities, which is called student agency and co-agency
Transformative Competencies and Competency Development	The essential competencies to adapt to the complex and uncertain society for a brighter future and required for fostering student agency, including creating new value, taking responsibility, reconciling dilemmas and tensions, anticipation, action, and reflection
Compound competencies	The competencies necessary for individual, societal, and environmental wellness, include global competency, media literacy, literacy for sustainable development, computational thinking/coding/programming, financial literacy, and entrepreneurship

Table 5 Criteria for determining competency levels (OECD, 2019b)

Level	Degree Description	Criteria
1	Not targeted in this learning area	There is no mention of this competency requirement in the text of this content subject in the standards, and teachers will not include it as part of their instruction
2	Not targeted in this learning area, but there are some opportunities for teachers to include this when teaching this learning area	There is no explicit target requirement for this competency in the text of this content subject in the standards. However, teachers may refer to the competency in the prescribed or recommended textbooks and in the interpretation of the curriculum standards when teaching
3	Sub-target of the learning area's branches/strands or in specific grades only	The competency is included in the written curriculum but only as a sub-target or the selected competencies are not clearly articulated in the curriculum
4	The main target of the learning area's branches/strands	The competency is included in the written curriculum as the main target or the selected competencies are clearly articulated in the curriculum

Table 6 Example of coding an item

Item	Content subject	Competency	Position	Competency level
Demonstrate and illustrate the function of various cellular structures and their interrelationships using, for example, diagrams or models (Ministry of Education (MoE), 2022a)	CSB1	Literacy	Academic requirements	3

Coding reliability

To ensure inter-rater reliability, four educators who were familiar with the content of NBCS (7–9) were involved in training, which included the interpretation of the OECD 2030 competencies and the general information about CCM. After the educators reached a consensus on the understanding of the content of the competency framework, the content subject of "the levels of biological organization" in the NBCS (7–9) was selected, and four educators independently coded this part with the code rules. The result showed a relatively high level of agreement among the four raters (Kendall $W = 0.789$, $\chi^2 = 194.049$, $p = 0.00 < 0.01$). After the pre-analysis reached a consensus, the raters independently analyzed the remaining text and finally aggregated the results of the analysis. Uncertain results were discussed. If no consensus was reached, an expert on biology curriculum and pedagogy was consulted to make a decision and further iterate to improve the rules of coding.

For example, regarding the item "Correct and standardized production of clinical slides, using a microscope for observation, be able to analyze the causes of poor imaging in the observation results from the aspects of material preparation, instrumentation, and operation procedures" (Ministry of Education (MoE), 2022a), there was agreement on the content subject coding but disagreement on the competency coding among raters A, B, C and D (see Table 7).

There were two major inconsistencies. The first concerns the possibility of coding "Action" in basic observational experiments. The second is that there were questions about the judgments of "Reflection" and "Learning to learn". In response to the inconsistency, the raters discussed it with the experts. After the discussion, it became clear that this item was consistent with the meaning of the "Action" code, which is "to utilize skills acquired to act or contribute to a situation or circumstances" (OECD, 2019b), and it was clarified that the scientific process of running experiments in a laboratory could be coded as "Action". The expert further clarified to the raters that "Learning to learn" is an awareness of the phenomenon of learning itself rather than knowledge. In comparison with "Reflection", "Learning to learn" also needs to reflect a process of adjustment or improvement of the program. Finally, all the raters reached a consensus that the competency codes for this item were "Reflection" and "Action".

Data analysis

To address our research question, we created a mapping grid that shows the relationship between the content subjects in the curriculum standards and the level of competency representation. Using this heat map, we counted the total number of competencies covered by NBCS (7–9), as well as the degree of embodiment of each competency category. In addition, we analyzed the frequency and percentage of different competency levels in each content subject, which allowed us to examine to what extent the curriculum standards are developing specific competencies within different content subjects.

Result

Mapping grid of the curriculum content

Based on the analysis of the NBCS (7–9) and supporting materials, a mapping grid was created to demonstrate the representation of competencies in the seven content subjects (see Fig. 1). The result shows that all five dimensions of competency are represented to some degree, with Foundational Literacies and Transformative Competencies and Competency Development being represented at a high level. Skills, Attitudes, and Values focus mainly on Problem-solving, Respect, and Cooperation/Collaboration. Key Concepts are primarily focused on Student Agency and Co-agency in certain content subjects. Compound Competencies are represented at the weakest level, with an emphasis on Global Competency and Literacy for Sustainable Development in certain content subjects. The NBCS (7–9) addresses 20 out of the 28 specific competencies (71.4%) while failing to address the remaining eight competencies, including Self-regulation/Self-control, Empathy, Trust, Reconciling Dilemmas and Tensions, Media Literacy, Computational Thinking/Coding/Programming, Financial Literacy, and Entrepreneurship.

Table 7 Example of a coding inconsistency

Item	Content subject	Rater	Competency
Correct and standardized production of clinical slides, using a microscope for observation, be able to analyze the causes of poor imaging in the observation results from the aspects of material preparation, instrumentation, and operation procedures (Ministry of Education (MoE), 2022a)	CSB1	A	Reflection, Action
		B	Reflection
		C	Reflection
		D	Reflection, Learning to learn, Action

Competencies / Content Codes	Foundational Literacies					Skills, Attitudes and Values									Key Concepts		Transformative Competencies and Competency Development						Compound Competencies					
	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
CSB1	4	2	4	1	1	2	2	4	1	1	1	1	1	2	1	4	1	1	1	3	4	3	1	1	1	1	1	1
CSB2	4	2	2	2	2	2	2	2	1	1	4	2	1	2	3	2	1	4	1	2	4	2	2	1	2	1	1	1
CSB3	4	3	2	3	2	3	2	4	1	1	4	2	1	1	2	2	3	3	1	3	4	2	4	1	4	1	1	1
CSB4	3	2	2	2	3	2	2	3	1	2	1	2	1	2	1	2	1	1	1	2	4	2	1	1	1	1	1	1
CSB5	3	2	2	2	3	3	2	4	1	2	4	4	1	2	2	2	4	1	2	3	4	2	2	1	2	1	1	1
CSB6	3	2	2	2	2	3	2	3	1	2	2	2	1	2	2	1	1	2	1	2	4	1	1	1	1	1	1	1
CSB7	4	1	3	3	4	4	3	4	1	1	4	3	1	3	2	2	4	4	2	2	4	3	2	2	2	1	1	1

Fig. 1 Mapping grid of the Chinese National Biology Curriculum for middle school

Percentage of content subjects rated as main or sub-targets

To give a clearer illustration of whether individual competencies are identified as main or sub-targets in Biology, the proportion of content subjects that explicitly require the competencies according to the curriculum objectives (i.e., competency elements with representation levels 3 and 4) was calculated based on the result from the mapping grid. Figure 2 shows that Action and Literacy are prominent in the NBCS (7–9), with all content subjects presenting these competencies as main or sub-targets. Problem-solving is also well represented, with 85.7% of

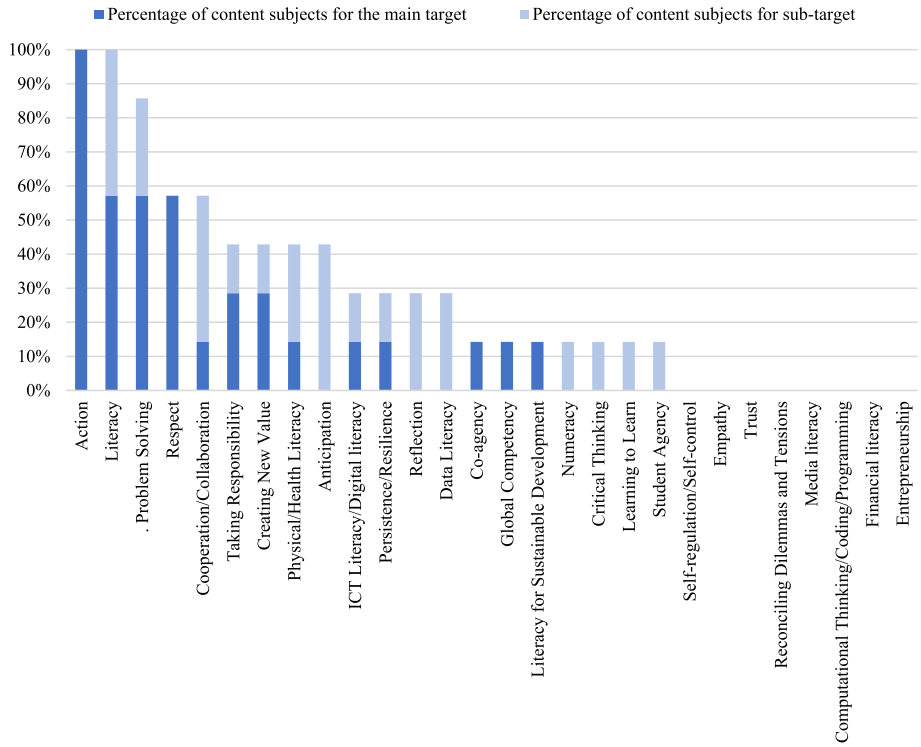

Fig. 2 Percentage of content subjects rated as main or sub-targets

content subjects incorporating this competency. Respect and Cooperation/Collaboration are included in four content subjects (57.1%). Taking Responsibility, Creating New Value, Physical/Health Literacy and Anticipation are included in three content subjects (42.9%). ICT Literacy/Digital literacy, Persistence/Resilience, Reflection, and Data Literacy are included in two content subjects (28.6%). Co-agency and the other seven competencies only appear in one content subject (14.3%).

Content subject analysis

Table 8 shows the representation of each competency dimension as the main or sub-target within each content subject. It can be seen that Foundational Literacies, Skills, Attitudes and Values, Transformative Competencies and Competency Development are present in all content subjects, while Key Concepts and Compound Competencies are the least represented. The content subjects CSB1 and CSB2 primarily focus on Foundational Literacies and Transformative Competencies and Competency Development. CSB3 emphasizes Skills, Attitudes and Values, Transformative Competencies, and Competency Development. Both CSB4 and CSB6 focus on Transformative Competencies and Competency Development. CSB5 and CSB7 cover Foundational Literacies, Skills, Attitudes and Values, and Transformative Competencies and Competency Development.

The frequency of items representing different competencies within each content subject was analyzed further, as shown below.

In CSB1, seven competencies are covered in the NBCS (7–9) (Fig. 3). The most common competency is Action, which is present in the main target 16 times and in the sub-target nine times, accounting for 55.6% of all coded items. The next most common competency is Literacy, which appears four times in the main target and nine times in the sub-target, accounting for 28.9% of all coded items in the standards. Other competencies present in the NBCS (7–9) included ICT Literacy/Digital literacy, Co-agency, Anticipation, and Reflection. This content

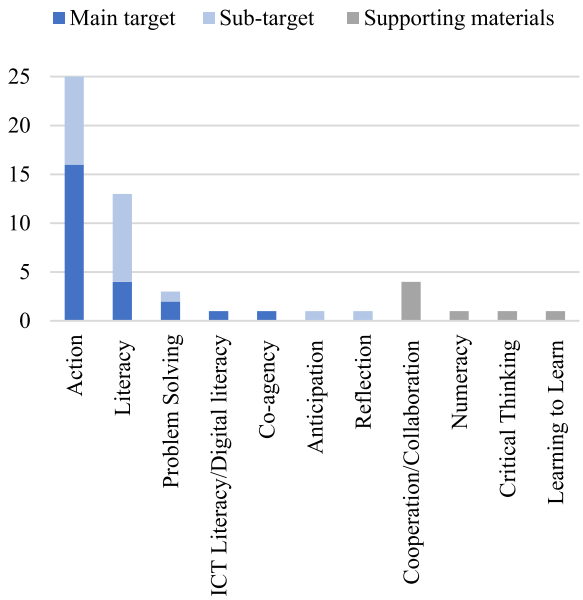

Fig. 3 Frequency of coding items in CSB1

subject, which focuses on the structural levels of organisms, involves the study of structures at different scales, from microscopic to macroscopic. The NBCS (7–9) requires students to use microscopes in the laboratory to observe various structures, such as cells, tissues, and organs, and to summarize and present their findings using schematics or models. As a result, this content subject places a strong emphasis on developing students' Action and Literacy. The supporting materials for CSB1 also mention the competencies of Cooperation/Collaboration, Numeracy, Critical Thinking, and Learning to Learn, which are not explicitly mentioned in the text of the corresponding content subjects in the standards.

In CSB2, there are five competencies covered (Fig. 4). The most common competency reflected in the NBCS (7–9) is Action, which appears 12 times in the main target, making up 48.0% of the total. Literacy appears six times in the main target and once in the sub-target, accounting for 28.0% of the total. Respect is reflected in

Table 8 Sources of content subjects for main or sub-targets items

	Foundational Literacies	Skills, Attitudes, and Values	Key Concepts	Transformative Competencies and Competency Development	Compound Competencies
CSB1	14	3	1	27	0
CSB2	7	3	1	14	0
CSB3	6	19	0	29	2
CSB4	3	3	0	9	0
CSB5	10	15	0	18	0
CSB6	2	2	0	5	0
CSB7	34	21	0	49	0

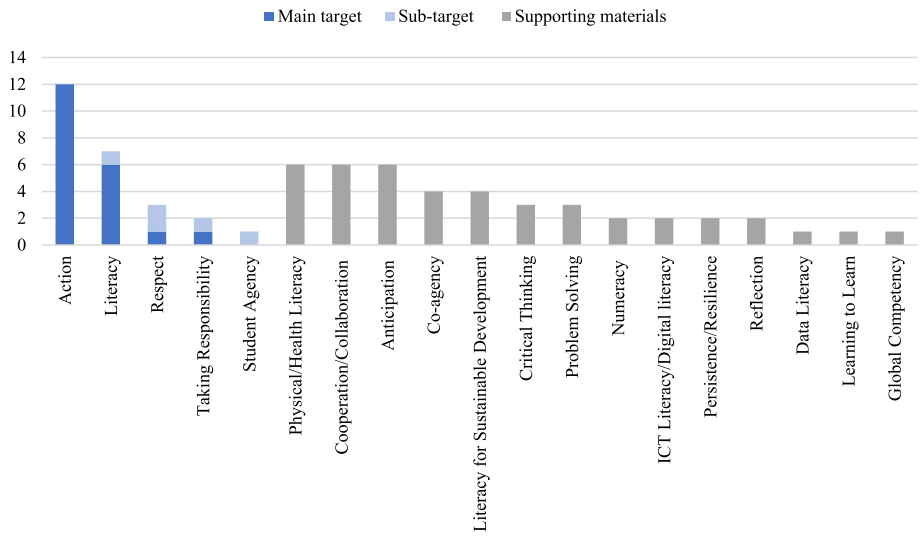

Fig. 4 Frequency of coding items in CSB2

the standards, once in the main target and twice in the sub-target, making up 12.0% of the total. Responsibility and Student Agency are also embedded in the standards. This content subject focuses on the classification of species, collection of information, and outdoor investigations and emphasizes the importance of protecting biodiversity, and compliance with relevant laws and regulations, thus achieving the development of Action, Literacy, Respect, and Taking Responsibility. The supporting materials for this content subject also cover 14 competencies that are not reflected in the NBCS (7–9), including Physical/Health Literacy, Cooperation/Collaboration, Anticipation, Co-agency, Literacy for Sustainable Development, etc.

In CSB3, there are 12 competencies covered in the NBCS (7–9) (Fig. 5). Action is the most represented, with a total of 25 coded items in the main target or sub-target, accounting for 49.0%. Problem-solving is also highly represented, with five coded items in the main target and nine coded items in the sub-target, accounting for 27.5%. Respect and Literacy each have a total of four coded items, accounting for 7.8% each. Creating New Value

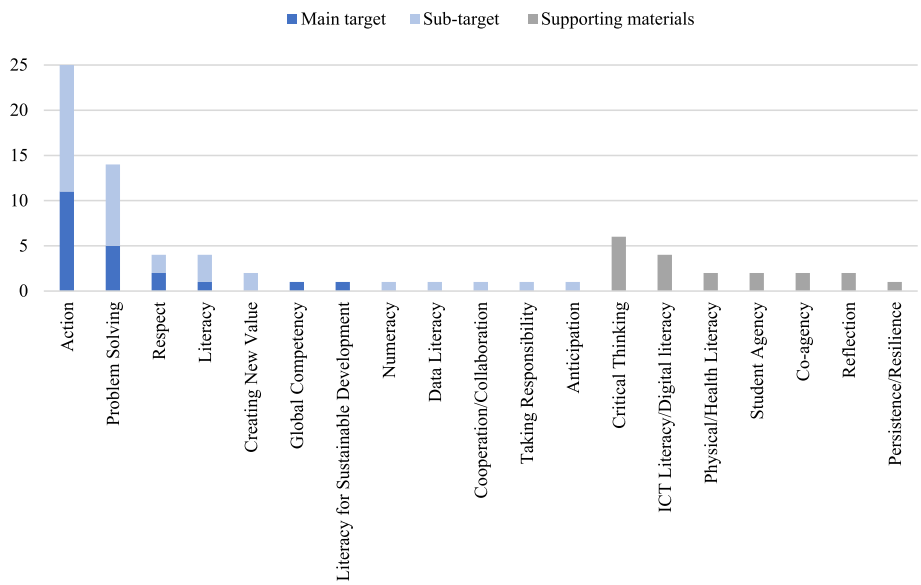

Fig. 5 Frequency of coding items in CSB3

appears two times in the sub-target, accounting for 3.9%. Global Competency, Literacy for Sustainable Development, and Numeracy each have one coded item in the main target or sub-target of the standards. The NBCS (7–9) in this content subject requires students to collect information related to ecosystems, design experiments in groups to investigate the effects of the environment on living things, record data, and write reports after analyzing and summarizing. The content subject also involves designing ecological bottles using interdisciplinary knowledge and methods, which reflects the requirements for Action, Problem-solving, and Respect and Literacy. The supporting materials also reflect seven competencies not presented in the corresponding content subjects of the NBCS (7–9)NBCS (7–9), including Critical Thinking, ICT Literacy/Digital Literacy, Physical/Health Literacy, Student Agency, Co-agency, Reflection, and Persistence/Resilience.

In CSB4, the NBCS (7–9) covers four literacy competencies (Fig. 6). Action is the most represented competency, appearing in the main target two times and in the sub-target seven times, accounting for 60.0%. Problem-solving appears three times in the sub-target, accounting for 20.0%. Literacy is represented twice in the sub-target, accounting for 13.3%. Physical/Health Literacy is also represented once in the sub-target, accounting for 6.7%. This content subject focuses on activities related to animal breeding and plant cultivation, requiring students to create appropriate devices for observing and recording the growth and development of living things. It also covers content related to human reproduction and development during adolescence, requiring students to develop good hygiene habits in response to the physical and psychological changes that occur during this time. These activities emphasize the development of Action, Problem-solving skills, Literacy, and Physical/Health Literacy. The supporting materials for this content subject also reflect 11 competencies not mentioned in the curriculum for the corresponding content subjects, including Data Literacy, Co-agency, Critical Thinking, Empathy, etc.

The result of the analysis of CSB5 shows that there are nine competencies covered in the NBCS (7–9) (Fig. 7). Action appears the most frequently, with 11 appearances in the main target and four in the sub-target, accounting for 34.9%. Problem-solving appears nine times in the main target and three times in the sub-target, making up 27.9%. Physical/Health Literacy appears eight times in the sub-target, accounting for 18.6%. Creating New Value appeared once in the main target and once in the sub-target, making up 4.7%. Literacy appears twice in the sub-target, accounting for 4.7%. Respect and Persistence/Resilience each appeared once in the main target, accounting for 2.3%. The content subjects mainly include inquiry experiments related to animal and plant life, the human body, and health, which require students to design experimental protocols or combine multidisciplinary knowledge to design experimental devices. The 12 competencies reflected in the supporting materials and not embodied in the NBCS (7–9) are Data Literacy, Numeracy, ICT Literacy/Digital Literacy, Critical Thinking, Reflection, etc. Among these, Data Literacy makes up a relatively high percentage, with the textbooks and the interpretation of curriculum standards often using the form of analyzing data charts related to life activities to draw conclusions to develop this competency.

In CSB6, four competencies are addressed in the NBCS (7–9) (Fig. 8). The most frequent competency is Action, which appears three times in the main target and two

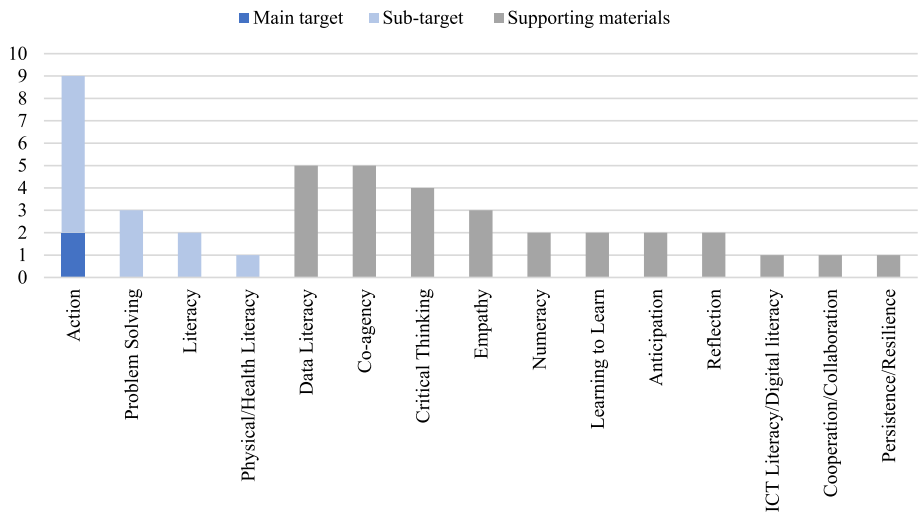

Fig. 6 Frequency of coding items in CSB4

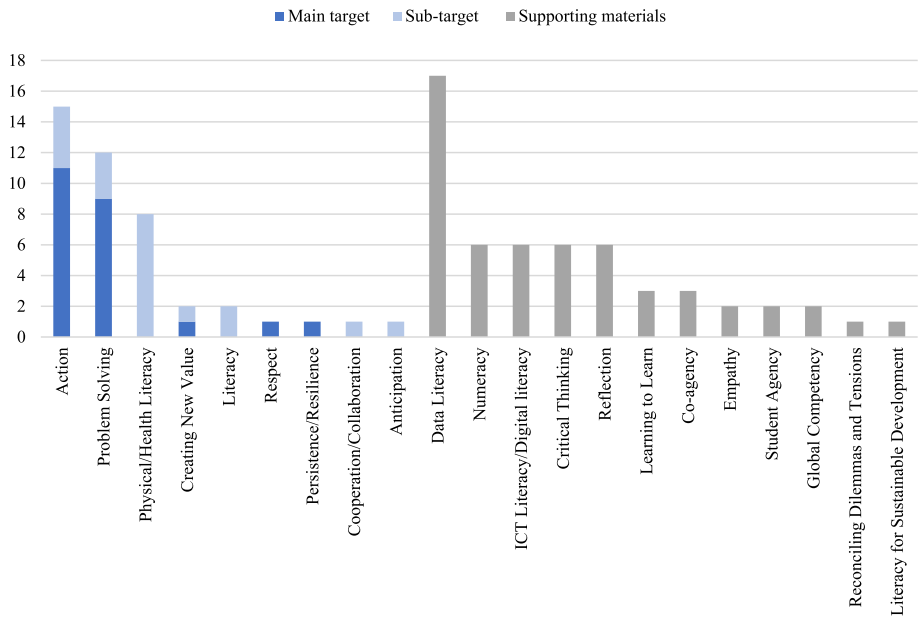

Fig. 7 Frequency of coding items in CSB5

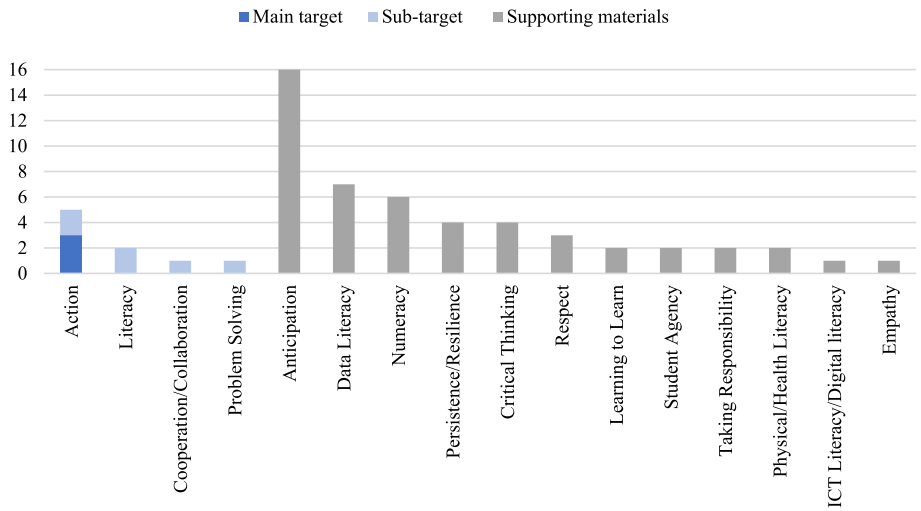

Fig. 8 Frequency of coding items in CSB6

times in the sub-target, representing 55.6%. Literacy appears 2 times in the sub-target, representing 22.2%. Cooperation/Collaboration and Problem-solving both appear once in the sub-target, representing 11.1% each. This content subject primarily includes simulated experiments to investigate the transmission of chromosomes during reproduction and investigating phenomena related to heredity, with students communicating and discussing in groups during the process. This reflects the development of Action, Literacy, Cooperation/Collaboration, and Problem-solving. The supporting materials also mention 12 competencies, such as Anticipation, Data Literacy, Numeracy, Persistence/Resilience, Critical Thinking, and Respect, with Anticipation appearing more frequently. This competency is primarily developed in this content subject through anticipating the origin of life and the process of biological evolution through information and making hypotheses in simulated genetic experiments.

In CSB7, 14 competencies are covered (Fig. 9). Of these, Action appears 18 times in the main target and 15 times in the sub-target, making up 31.7% of the coding items

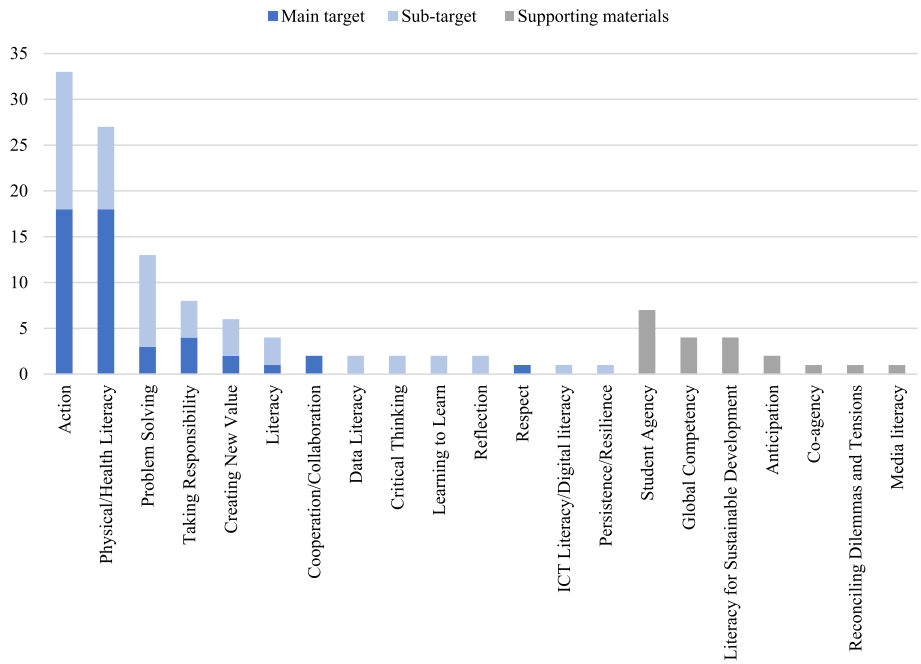

Fig. 9 Frequency of coding items in CSB7

in NBCS (7–9). Physical/Health Literacy also appears 18 times in the main target and nine times in the sub-target, comprising 26.0%. Problem-solving appears three times in the main target and ten times in the sub-target, representing 12.5%. Taking Responsibility appears four times in both the main and sub-target, accounting for 7.7%. Creating New Value appears two times in the main target and six times in the sub-target, making up 5.8%. Literacy appears one time in the main target and three times in the sub-target, representing 1.92%. Additionally, the curriculum includes a range of other competencies, such as Cooperation/Collaboration, Data Literacy, Critical Thinking, Learning to Learn, and Reflection, etc. The content subject covers a wide range of topics, mainly requiring students to collect relevant information, investigate biology-related issues in society, and conduct biotechnology-related experiments, such as the making of yogurt and kimchi. It also includes using biology knowledge to solve socially relevant problems in daily life, promoting health-related knowledge, and developing a sense of social responsibility, thus cultivating competencies such as Action, Physical/Health Literacy, and Problem-solving. The textbook and interpretation of the standards reflect seven competencies that are not represented in the NBCS (7–9), including Student Agency, Global Competency, Literacy for Sustainable Development, Anticipation, Co-agency, Reconciling Dilemmas and Tensions, and Media Literacy.

Discussion

The result of the analysis shows that out of the 28 competencies, 20 are mentioned in the content subjects corresponding to the Level 4 or Level 3 standards. These include Literacy, Numeracy, ICT Literacy/Digital literacy, Data Literacy, Physical/Health Literacy, Cooperation/Collaboration, Critical Thinking, Problem-solving, Respect, Persistence/Resilience, Learning to Learn, Student Agency, Co-agency, Creating New Value, Taking Responsibility, Anticipation, Action, Reflection, Global Competency, and Literacy for Sustainable Development. This indicates that the Chinese Biology Curriculum places a strong emphasis on these 20 competencies and reflects their development in the core parts of the curriculum standards, such as the content requirements, academic requirements, and teaching tips. This aligns well with the OECD 2030-oriented learning framework. Further analysis reveals that Cooperation/Collaboration, Respect, and Problem-solving are present in more than half of the content subjects, while Literacy and Action are present in all of the content subjects. This highlights the importance that the NBCS (7–9) places on the development of these competencies.

Some competencies, such as Empathy, Reconciling Dilemmas and Tensions, and Media Literacy, are only partially reflected in the interpretation of the curriculum standards or the textbook, while Self-regulation/Self-control, Trust, Computational Thinking/Coding/

Programming, Financial Literacy, and Entrepreneurship are not addressed at all in the NBCS (7–9) or the supporting materials. These competencies have weaker attributes in biology compared to Action, Literacy, and Problem-solving, which have more explicit requirements in the curricula of other disciplines. Specifically, Empathy, Reconciling Dilemmas and Tensions, Trust, and Self-regulation/Self-control are more prominent in moral education. For example, one of the main targets of *National Ethics and the Rule of Law Curriculum Standards (Grades 1–9)*, is "to be able to independently regulate one's emotional fluctuations, to have good communication skills, and to take the initiative to establish good interpersonal relationships" (Ministry of Education (MoE), 2022b, p.14), reflects the requirement for Self-regulation/Self-control. Computational thinking is more emphasized in information technology education. For example, *National Information Technology Curriculum Standards (Grades 1–9)* put computational thinking as one of the key competencies of the information technology discipline. In the main target, students are required to "be able to define problems, analyze problems, organize data, formulate solutions to problems using ideas and methods in the field of computer science and reflect on and optimize them, use simple algorithms to utilize computers, and use simple algorithms to solve problems using computers" (Ministry of Education (MoE), 2022c, p.6). Financial literacy and Entrepreneurship may be more closely linked to disciplines related to the social sciences.

The result of the analysis of competencies in each content subject shows that some competencies are not reflected in the NBCS (7–9) but were present in the supporting materials. In more than half of the content subjects, the number of types of competencies reflected in the supporting materials alone exceeded the number of types of competencies present in the NBCS (7–9) alone. This is partly because Chinese curriculum standards are programmatic, coarse-grained documents that do not contain much detail. Teaching materials are based on the curriculum standards and can systematically reflect the content of the subject, which is the materialization of the curriculum standards. The interpretation of curriculum standards is an aid to comprehensive analysis and interpretation of the expectation, learning area, and academic quality of the curriculum standards. Together, curriculum standards, interpretations of curriculum standards, and teaching materials together explain the requirements for student development. Because of this, the supporting materials' text has more detail than NBCS (7–9) does, making it simpler to reflect the standards for competency development.NBCS (7–9) It partly suggests that each content subject has the potential to develop a more diverse and comprehensive range of competencies for students. For instance, CSB6, which covers making inferences about genetic phenomena and data computation and analysis related to genetic evolution, can develop Anticipation, Data Literacy, Computational Thinking/Coding/Programming, and other competencies to some extent.

To summarize, those involved in the development of China's curriculum standards can determine whether and to what extent the OECD 2030-oriented learning framework has been reflected in NBCS (7–9) by combining the results of CCM analysis, and can then further revise the curriculum standards in light of China's actual environment and the trend of international curriculum reform. It is possible to consider the compatibility of each competency with various content subjects in light of the distribution pattern of those content subjects and their frequency, as well as to weigh the proportion of various competency development in NBCS (7–9), to better integrate those competencies with the curriculum. For the eight competencies that are not directly required in NBCS (7–9), it is important to think about how well they fit with the nurturing characteristics of the biology discipline, and whether it is necessary to make the requirements for these competencies explicit in NBCS (7–9). The outcomes of CCM analysis in other nations can also be used to examine whether these competencies are reflected in the learning standards for other nations' biology curricula.

The findings of the analysis of NBCS (7–9) can also offer some general ideas and inspirations for developing and implementing curricula for other nations and regions. Different competencies have different discipline or content subject attributes. Nations or regions can use CCM to fully understand and build a system of future-oriented competency objectives and content subjects, combine the unique characteristics and values of that content subject in biology, identify the competencies suitable for cultivation in each content subject, and translate them into explicit and clear curriculum content requirements in the NBCS (7–9), to better guide teachers' teaching and students' learning.

As evidence, the analysis of NBCS (7–9) revealed that Action, Literacy, and Problem-solving may be effectively incorporated into the majority of content subjects. These are probably skills that the biology curriculum can work to improve. NBCS (7–9) The results of the analysis indicate that Action is highly represented in all content subjects, indicating its prominence in the NBCS (7–9). Additionally, Literacy and Problem-solving are also consistently emphasized, with a high level of representation in the majority of content subjects. This can be attributed to the practical and inquiry-based nature of biology as a natural science, which requires students to engage in

hands-on activities and investigations. The NBCS (7–9) includes inquiry practice as a core component of competency development in biology, as demonstrated by the prevalence of laboratory and outdoor investigation activities that require Action. The design of research proposals and the proposal of ideas or solutions to problems also allow for the development of Problem-solving in biology and across disciplines. Moreover, the opportunity for students to express and communicate their findings through written, oral, and visual forms, such as research reports, models, and data visualizations, emphasizes the importance of Literacy in each content subject.

The result of the analysis also reveals that certain competencies exhibit adaptability with specific content subjects. For example, Physical/Health Literacy is more prominently represented in content subjects CSB4, CSB5, and CSB7, likely due to the inclusion of topics related to physical and psychological changes during adolescence, human health, and the formation of health awareness and good habits in social life. Similarly, Global Competency and Literacy for Sustainable Development are more prominent in content subject CSB3, likely due to the inclusion of topics related to ecological safety, such as global climate change and environmental pollution, which allow students to develop an awareness of global interconnectedness and to analyze problems from a global perspective while considering issues related to ecological protection and sustainable resource utilization.

Limitations and research opportunities

This study aims to examine the extent to which the OECD 2030-oriented competencies are reflected in the seven content subjects of the NBCS (7–9). It should be noted that this study only analyzed texts in the NBCS (7–9) that have explicit content pointers, such as the expectation section outlining the requirements for competency within the discipline of biology. Therefore, it is possible that this study may not fully reflect all of the competencies present in the NBCS (7–9). While only the most widely used biology textbook (Grades 7–9) in China was analyzed, some competencies in other biology textbooks could be missed. Additionally, the NBCS (7–9) was recently revised in 2022, but the corresponding textbooks have not yet been updated, so the result may not fully reflect all of the competencies in Level 2. Future research also could focus on examining the reflection of competencies in the curriculum standards ranging from elementary to high school, comparing the distribution of competency across different levels, and conducting a longitudinal comparative study from the perspective of progression.

Conclusions

This study used the OECD 2030-oriented competency framework to examine the representation of competency in the NBCS (7–9), created a mapping grid in an overall perspective, and analyzed the representation of competency in each of the seven content subjects. The findings of this study provide a review and reflection on the NBCS (7–9) from the perspective of future competency, to further revise and improve the curriculum standards. It will also help other countries to learn from or draw on the experience of reforming curriculum standards, and to design curriculum standards at the upper level in the light of the links between different disciplines, content subjects and competency, to enhance the future key competency of students.

Abbreviations

ACARA	Australian Curriculum Assessment to Reporting Authority
CCM	Curriculum Content Mapping
NBCS (7–9)	*National Biology Curriculum Standards (Grades 7–9)*
DfE	Department for Education
MoE	Ministry of Education
MoES	Ministry of Education, Singapore
NGSS	Next Generation Science Standards
OECD	Organization for Economic Cooperation and Development
P21	Partnership for 21st Century Learning
UNESCO	United Nations Educational, Scientific, and Cultural Organization

Acknowledgements
Not applicable.

Authors' contributions
JW contributed to the study conception and design, the drafting and the substantial review of the work, and has approved the submitted version. SL, XRL, XDT, CS and MXT contributed to the material preparation and data analysis. The first draft of the manuscript was written by SL. JW and TL substantively revised the first draft. JW and SL contributed to the manuscript's revision and writing. All the authors read and approved the submitted manuscript.

Funding
No funding was received.

Availability of data and materials
The datasets used and/or analyzed during the current study are available from the corresponding author on reasonable request.

Declarations

Ethics approval and consent to participate
Not applicable.

Consent for publication
Not applicable.

Competing interests
The authors declare that they have no competing interests.

Received: 5 July 2023 Accepted: 10 October 2023
Published online: 17 November 2023

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