Journal of Education, Society and Behavioural Science

Volume 36, Issue 11, Page 70-81, 2023; Article no.JESBS.109741
ISSN: 2456-981X
(Past name: British Journal of Education, Society & Behavioural Science,
Past ISSN: 2278-0998)

A Cross-National Comparison of curricula in China and the US in Terms of Team Education: The Case of One-Dimensional Equation

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Authors' contributions

This work was carried out in collaboration between both authors. Both authors read and approved the final manuscript.

Article Information

DOI: 10.9734/JESBS/2023/v36i111279

Open Peer Review History:
This journal follows the Advanced Open Peer Review policy. Identity of the Reviewers, Editor(s) and additional Reviewers, peer review comments, different versions of the manuscript, comments of the editors, etc are available here: https://www.sdiarticle5.com/review-history/109741

Original Research Article

Received: 21/09/2023
Accepted: 25/11/2023
Published: 04/12/2023

ABSTRACT

Based on the STEAM concept, researchers study the two representative secondary school mathematics textbooks in China and America by using a quantitative analysis method and get the following conclusions: similarities: both textbooks embody the concept of STEAM education, focusing on the breadth of knowledge covered by the textbooks; both textbooks focus on the integration of disciplines, especially on the integration of mathematics and science and technology. Differences: The focus of the two countries' textbooks is different. The Chinese PEP textbook emphasizes the knowledge of history and environmental engineering, while the American GMH textbook is more diversified and covers a wider range of knowledge and culture, reflecting the distinctive national characteristics of the two countries; the Chinese PEP textbook has a deeper depth of knowledge as a whole, while the depth of knowledge of the American GMH textbook about engineering is deeper than that of the PEP textbook; the Chinese PEP textbook pays more

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attention to the integration of technology in the mathematics textbook. China's PEP materials place more emphasis on the integration of technical subject knowledge in math materials, while American materials place more emphasis on the integration of engineering knowledge and art knowledge in math materials. By analyzing and evaluating the integration of STEAM concepts into junior high school mathematics textbooks in two countries, this study provides implications for mathematics education researchers and workers, especially textbook developers and writers, in this direction of research.

Keywords: STEAM education; STEM education; mathematics teaching materials; comparison of teaching materials; integration of disciplines.

1. INTRODUCTION

STEAM education originates from the United States. In terms of its disciplinary composition, STEAM education consists of five elements, including science, technology, engineering, art, and mathematics [1]. Among them, science is the basis of engineering design; technology is a tool; engineering is the output as the goal, with practice-oriented; art can develop students' imagination and innovation creativity; mathematics is the basis for students in the process of problem-solving, reasoning, proof, computation are missing no math. STEAM education is the core concept of cross-disciplinary integration, where the integration of cross-disciplinary is not simply a mechanical linear combination of knowledge from five disciplines, but rather a combination of independent and independent of different disciplines, and mathematics. Five disciplines of knowledge are linear combinations, but the different disciplines of independent and dispersed knowledge and skills, through the use of new pedagogical methods and problem-solving processes, ultimately realize the organic fusion of multidisciplinary knowledge [1].

Mathematics is one of the five disciplines of STEAM and a very important basic subject. China's newly promulgated curriculum standards pay more and more attention to the integration of mathematics in social production activities and the practicality and activity of mathematics learning as well as the integration between mathematics and other subjects. This coincides with the concept of STEAM education. Mathematics textbooks can provide effective and reliable references for front-line math teachers to explore how to better emphasize the students' subjective position, and also for more schools to start tapping their advantages and give students practical and hands-on opportunities [2]. Therefore, from the perspective of textbook analysis, this paper selects two repressive versions of textbooks from China and the United States, the origin of STEAM education, for comparative study.

In this paper, the units on quadratic equations in two versions of secondary school mathematics textbooks in China and the United States are chosen as the objects of study. The Chinese version is People's Education Publishing House (hereafter referred to as the PEP textbook), which was approved by the Ministry of Education (MOE) in 2012/2013 and is one of the most widely used textbooks in China. The U.S. version of the textbook is California-Algebra 1 (hereinafter referred to as the GMH textbook) published by Glencoe McGraw-Hill Publishing Company, which is widely used in the California region of the U.S. This textbook is representative of the U.S. version of the textbook. According to Google search results, researchers get that the PEP textbook has 65% of the market share, and the GMH textbook also has a relatively large market share, so the selection of these two editions of the textbook for comparing the Chinese and American math textbooks has a large representation [3]. The two editions are representative of comparing Chinese and American mathematics textbooks, and the problems related to quadratic equations, which is an important module in junior high school mathematics, can be better integrated with other sections, such as geometry and probability so that researchers can effectively conduct a comparative study on the embodiment of the STEAM concepts in the textbooks. The research questions which guided this study were:

1. What is the distribution of the number and coverage of knowledge points in the five

major areas of S, T, E, A, and M in the Chinese PEP textbooks and the American GMH textbooks?
2. what is the depth of knowledge of STEAM knowledge points in Chinese PEP and American GMH textbooks?
3. what is the situation of the integration of knowledge in Chinese PEP textbooks and U.S. GMH textbooks?

Based on the results of the above questions and the findings of the study, researchers explore whether there is any convergence or divergence of knowledge content in Chinese PEP textbooks and U.S. GMH textbooks, as well as the impact on the effectiveness of mathematics education.

1.1 Theoretical Framework

1.1.1 Research on STEAM education

Researchers pay much attention to exploring the theory of STEAM education, educational practices such as project-based learning and the application areas of STEAM education, STEAM Creative Education, and cultivating STEAM education innovation in the application of talent, lack of research on the top-level design [4]. Since the United States put forward the concept of STEAM education in 2006, many countries have also carried out education related to it, and our country is no exception, there are some research results in the design of teaching, curriculum design, and development, the content of creator education, in information technology education, in science education and other aspects. However, the progress of research in subject areas and in the study of teaching materials has been slower [5].

1.1.2 Research on textbook

In recent years, there has been an increasing number of academic discussions and practical studies on STEAM, most of which are related to the development of textbooks. Textbooks are the core of curriculum content, and subject teaching is a key factor in STEAM learning and an important resource for teachers to organize students' learning. Based on the concept of STEAM education, the U.S. FOSS, the U.S. SCIENCE, our experts and scholars on the Canadian BC Science W and other science textbooks were analyzed, in addition to China's science, physics, biology, chemistry, information technology, and other disciplines of the textbooks, integrated practical activities and other disciplines or will be the domestic and foreign science textbooks (such as China's Zhejiang education version of the textbook "Science", Japan's "New Science" in China, "New Science" in Japan, "Science Explorer" in the United States for comparative research and analysis, hoping to better integrate the concept of STEAM education into Chinese textbooks, and give some reference suggestions. The study mainly focuses on elementary school textbooks, followed by secondary school textbooks.

Comparative research on teaching materials based on the STEAM perspective is beginning to increase, but most of them are comparisons of the science teaching materials, and there is a lack of comparative research on math teaching materials, which is a gap in the study of STEAM education concepts. As a very important basic subject, the comparative analysis of math teaching materials is of great value for the application of the STEAM education concept [6].

2. METHODS

2.1 Materials Analyzed

The objects of this study come from relevant lessons on one-dimensional equations in Chinese and American mathematics textbooks. The People's Education Publishing House’s mathematics textbooks (PEP) and Glencoe McGraw-Hill Publishing Company’s mathematics textbooks (GMH). Table 1 shows the titles of all lessons devoted to one-dimensional equations in the PEP and GMH, respectively.

In this study, two coders jointly used the STEM Pyramid Structure Framework **Error! Reference source not found.** (see Table 2), Webb's Depth of Knowledge Framework [7], and the Knowledge STEAM Knowledge Convergence Framework [8] for pre-coding(see Table 3), ec coded in h problems was to and the results were subjected to a consistency Kappa test, and the three sets of Kappa values obtained were 0.739, 0.813, and 0.731, respectively, which all fell into the category of almost perfect consistency with a high degree of reliability (see Table 4).

Table 1. One-dimensional equation in PEP and GMH

PEP	GMH
Unit 3. Linear equation in one unknown	Unit 1 Foundations for Functions (Chapter 2 Solving Linear Equation)
3.1.1 Linear equation in one unknown	2-1 Writing Equations
3.1.2 Properties of equality	2-2 Solving Addition and Subtraction Equations
3.2 Solve an equation of one dimension-merge congener and transference	2-3Solving Equations by Using Multiplication and Division
3.3 Solve an equation of one dimension-remove the parentheses and the denominator	2-4 Solving Multi-Step Equations 2-5Solving Equations with the Variable on Each Side 2-6 Ratios and Proportions
3.4 Practical problems with one-dimensional equation	2-7 Percent of Change 2-8 Solving for a Specific Variable 2-9 Weighted Averages Extend2-9 Finding a Weighted Averages

Table 2. STEAM coding dimension

Discipline	S	T	E	A	M
Coding	Physics S-1	Medicine T-1	Aerospace E-1	Form and Structure A-1	Numbers and Operations M-1
	Biology S-2	Agriculture T-2	Architecture E-2	Game A-2	Algebra M-2
	Chemistry S-3	Biotechnology T-3	Agricultural Machinery E-3	Multilingualism A-3	Geometrical M-3
	Geosciences S-4	Manufacturing T-4	Chemicals E-4	Innate liberation A-4	Measurement M-4
	Space Science S-5	Information T-5	Civil Engineering E-5	Sociological A-5	Probabilistic analysis M-5
	Biochemistry S-6	Transportation T-6	Computer E-6	Pedagogical A-6	Problem-solving M-6
		Electricity T-7	Electromechanical E-7	Philosophy A-7	Reasoning and Proof M-7
		Energy T-8	Environmental Engineering E-8	Psychology A-8	Trigonometric function M-8
		Operaciones T-9	Marine Engineering E-9	Histories A-9	Infinitesimal calculus M-9
			Industrial Systems E-10	Statues A-10	Principles of Mathematics M-10
			Materials Science E-11	Literary A-11	Mathematical Model M-11
			Mechanical E-12 Minig Industry E-13	Concert A-12	

Table 3. Framework used for the analysis of mathematical problems in textbooks

Focus questions	Aspects investigated
1. What is expected in terms of the intellectual breadth of STEAM?	STEAM pyramid structure framework Science (S: S1~S6) Technology (T: T1~T11) Engineering (E: E1~E13) Arts (A: A1~A12) Mathematics (M: M1~M11)
2. What is expected in terms of the intellectual depth of STEAM?	Depth of knowledge (DOK) Level 1: recall/reproduce Level 2: skill/concept Level 3: strategic thinking Level 4: extended thinking
3. What is expected in terms of the intellectual integration of STEAM?	Disciplinary (R1) Multidisciplinary(R2) Interdisciplinary(R3) Transdisciplinary(R4)

Table 4. Kappa coefficient results

Source of Variation	kappa value	Standard error (assuming original hypothesis)	Z -value	P-value
Breadth	0.739	0.077	9.643	0.00
Depth	0.813	0.101	8.081	0.00
Integration	0.731	0.110	6.629	0.00

3. RESULTS

In Chinese People's Education Publishing House and American Glencoe McGraw-Hill Publishing Company's mathematical textbooks, one-dimensional equations are taught together in each unit in the two sets of materials. Table 5 gives the number of problems in the lessons about one dimensional for each set of textbooks. The GMH provides more problems than PEP (see Table 5).

3.1 Breadth of STEAM Knowledge

The researchers coded the problems in the unit on one-dimensional equations in the two editions of the textbook according to the framework in Table 2 and Table 3. The total number of problems in the GMH textbook is 2169, and the total number of problems in PEP is 520, which is less than a quarter of that in the United States. (Note: Since the object of this paper is the part of quadratic equations, most of each example problem involves two types of knowledge points, M1 numbers and their operations and M2 algebra, in order to be able to analyze the proportion of each part more clearly and intuitively, the researcher decided to analyze the data after eliminating the number of knowledge points of M1 and M2 in the two editions of the textbook, and the total number of knowledge points in PEP textbook after elimination is 182, and that in GMH textbook is 595). The number of knowledge points and the percentage of knowledge points in each part of S, T, E, A, and M in the two textbooks are shown in Table 5.

Table 5. Number of problems and lessons about linear equations with one unknown

	No. of problems	No. of lessons	Ave. no. of problems/lessons
PEP	177	19	9
GMH	770	30	27

Fig. 1 shows the distribution of five disciplines of the breadth of STEAM knowledge in the mathematical problems presented in the two sets of materials. Researchers can find that both the Chinese PEP textbook and the American GMH textbook on the unit of quadratic equations fully cover the five disciplines of S, T, E, A, and M. The knowledge content is comprehensive, which is basically in line with the requirements of STEAM education. Both Chinese and American textbooks have the richest content in the M category and the least in the E category. By comparing the knowledge points of each part of STEAM, it can be seen that the Chinese PEP textbook is M>S=T=A>E, and the U.S. GMH textbook is M>A>S>T>E. China's attention to the knowledge of science, engineering, and art is almost the same, while the U.S. pays more attention to the knowledge of art than to the knowledge of science, technology, and engineering.

In addition, this study also focused on the distribution of subject-specific knowledge in each subject.

In terms of the breadth of Science, the PEP was significantly less focused on biology, chemistry, and biochemistry than the GMH (see Fig. 2). In terms of the breadth of T-knowledge distribution, the PEP and the GMH have similar and diversified coverage of specific disciplines, with more emphasis on manufacturing and transportation, but no coverage of biotechnology and construction. In addition, compared to the PEP, the GMH also emphasizes information and communication knowledge (see Fig. 3). In terms of the distribution of knowledge in category E, both the PEP and the GMH focus on subject knowledge in aerospace, architectural design, and mechanics, but they do not cover agricultural machinery, chemicals, marine engineering, and mining. However, the PEP does not cover the knowledge areas of computers, electromechanics, and materials, which are the focus of the GMH. The PEP pays the most attention to the field of environmental engineering, while the GMH pays no attention to the subject area of environmental engineering (see Fig. 4). In the distribution of Arts, both the PEP and the GMH focus on sociology, history, and other knowledge, with the PEP paying significantly more attention to the subject of history than the GMH. The GMH focuses on a wider range of areas than the PEP, for example, language, emancipation of nature, sculpture, and especially literature and music are areas that are covered in the GMH but not in the PEP (see Fig. 5).

Table 6. Percentage of one-dimensional equation problems per STEAM knowledge breadth

	PEP (N=182)	GMH(N=595)
S	22(12.1%)	71(11.9%)
T	22(12.1%)	38(6.4%)
E	14(7.7%)	22(3.7%)
A	22(12.1%)	111(18.7%)
M(except M1、M2)	102(56.0%)	353(59.3%)

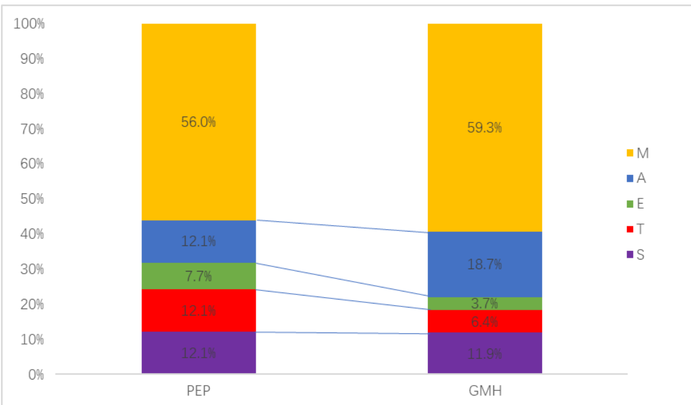
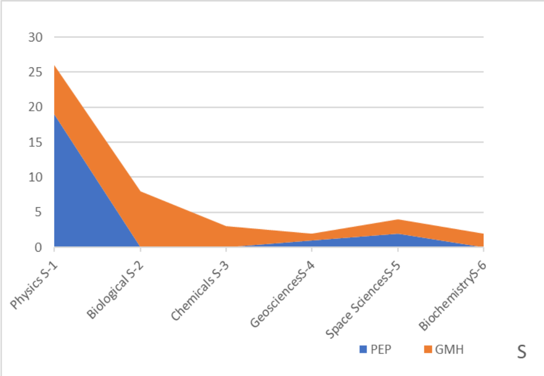


Fig. 1. One-dimensional equation problems according to Breadth of STEAM knowledge



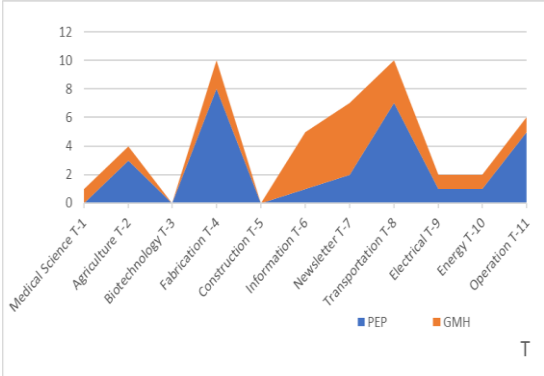
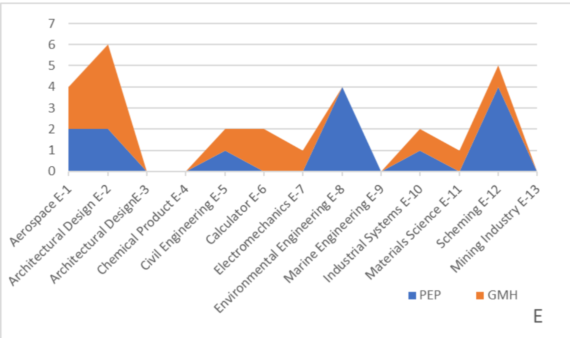


Fig. 2. Distribution of Knowledge Points of Science; Fig.3 Distribution of Knowledge Points of Technology



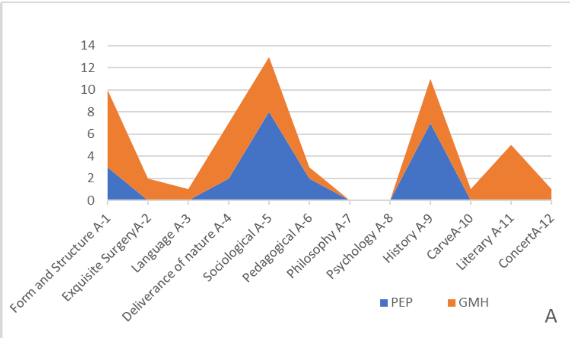


Fig.4 Distribution of Knowledge Points of Engineer; Fig. 5. Distribution of knowledge points of arts

3.2 Depth of STEAM Knowledge

In terms of the overall depth of knowledge, the PEP and the GMH differ significantly: the depth of knowledge in the PEP is higher than that in the GMH, and although both textbooks place great emphasis on the use of basic knowledge/skills, the PEP has a significantly higher proportion of knowledge at the Extensive Thinking level than the GMH, while the GMH has a higher proportion of knowledge at the Recall and Reproduction level than the PEP. In addition, the depth of knowledge profiles of PEP and GMH in each subject of S, T, E, and A are very different.

The depth of knowledge points in S, T, and A subjects are mainly concentrated in level 2, the PEP and the GMH both tend to exercise the students' ability to use quadratic equations to solve scientific problems. In addition, the number of S distributed in Level 3 and Level 4 in the two textbooks is relatively similar, but both are less than that distributed in Level 2, which shows that the two textbooks pay more attention to the application of quadratic equations, based on which some strategic thinking and extended thinking training will be conducted (see Fig. 7, Fig. 8 and Fig. 10). In terms of E, the depth of knowledge required for E in PEP mainly focuses on level 2, while the depth of knowledge for E in GMH not only stays at level 2 but also focuses on students' level 4 (see Fig. 9). Engineering knowledge requires students to create new products or methods after exploration, and the GMH textbook's depth of E knowledge is designed to be more in line with engineering concepts.

3.3 Integration of Knowledge

The proportion of knowledge points belonging to disciplinary in both PEP and GMH occupies the largest proportion, and the proportion of disciplinary knowledge points in GMH is higher than that in PEP, and the author also clearly noticed that the number of exercises on simple equations in GMH is very large, and the number of them is much higher than that in PEP. The proportion of knowledge points belonging to the multidisciplinary level in PEP and GMH is relatively close. Nearly one-quarter of the knowledge points belong to interdisciplinary in PEP.

About one-quarter of the knowledge points in the PEP are interdisciplinary, and the percentage of knowledge points at the interdisciplinary level in the GMH is slightly lower than in the PEP. The percentage of transdisciplinary problems is much higher in the PEP than in the GMH. The percentage of knowledge points integrating two or more disciplines (including the two levels of interdisciplinary and transdisciplinary) in the GMH is lower than in the PEP (see Figure 11).

In addition, of the knowledge belonging to the supra-disciplinary level in the PEP and GMH textbooks, the number of problems integrating disciplines is ranked in order of quantity: S>T>A>E in the PEP, and A>S>T>E in the GMH, which shows that there is a big difference in the specific disciplines in which transdisciplinary problems are integrated in the two textbooks. Nearly half of the transdisciplinary level problems in the GMH integrated A art disciplines, which was much higher than that in the PEP. The proportion of transdisciplinary problems integrating science and technology disciplines was much larger in the PEP than in the GMH (see Table 7).

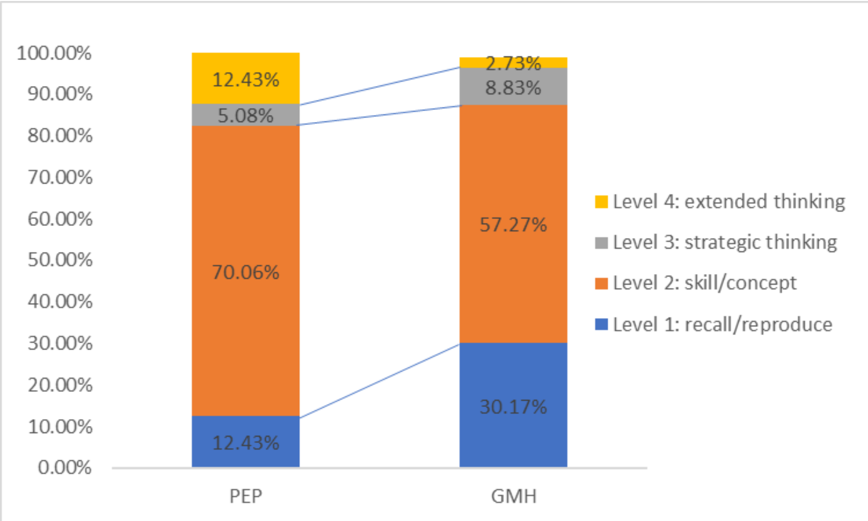
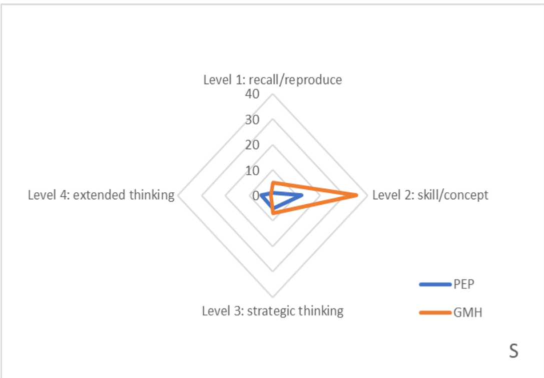


Fig. 6. Percentage of one-dimensional equation problems per depth of knowledge level



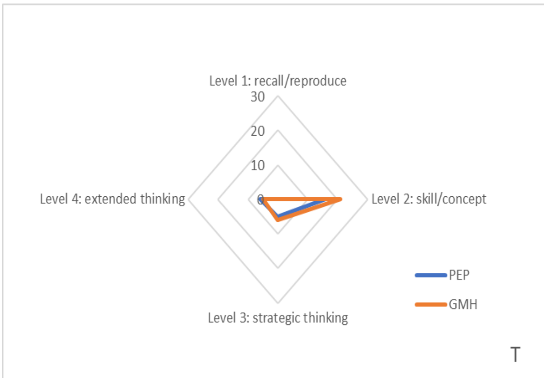


Fig. 7. Coverage of S in the depth of knowledge; Fig. 8 Coverage of T in the depth of knowledge

Fig. 9. Coverage of E in the depth of knowledge; Fig. 10. Coverage of A in the depth of knowledge

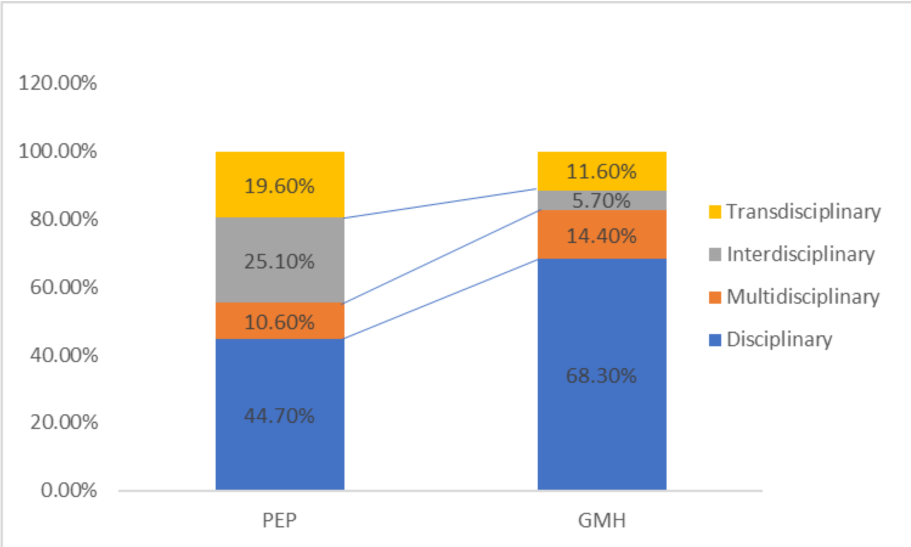


Fig. 11. Percentage of one-dimensional equation problems per integration of knowledge

Table 7. Percentage of transdisciplinary problems per STEAM integration

	PEP (N=45)	GMH (N=81)
S	19(42.2%)	21(25.9%)
T	16(35.6%)	12(14.8%)
E	3(6.7%)	9(11.1%)
A	7(15.6%)	39(48.1%)

4. DISCUSSION AND SUMMARY

4.1 Discussion

First, the STEAM education concepts are appropriately reflected in the curriculum standards. The concept of STEAM education helps to promote interdisciplinary learning and breaks down the isolation of traditional academic programs. It also has a positive effect on stimulating students' creative thinking and behavior [9]. Although the term "STEAM" does not appear in China's new compulsory education mathematics curriculum standards, it is mentioned that it is necessary to establish interdisciplinary thematic learning activities, strengthen interconnections between disciplines, and lead the implementation of curriculum synthesis, which are all in line with the concept of STEAM education [10]. 2017 Compulsory

Primary Science Curriculum Standards clearly articulate the STEAM concept. Curriculum Standards for Compulsory Education Elementary School Science in 2017 clearly explains the definition of STEM and puts forward some suggestions on its application in teaching, and it may not be a practical and innovative attempt to appropriately reflect the educational concept of STEAM in the math curriculum standards [11].

Secondly, while maintaining the characteristics and strengths of the materials, the coverage of knowledge is constantly expanded.

Compared with GMH, PEP incorporates more knowledge about history and environmental engineering [12,13]. School education is an indispensable part of all young people's education, and the teaching materials play a significant role in the teaching process and in their influence on the students, and the historical and humanistic spirit and the concept of symbiosis between human beings and the environment permeating PEP teaching materials play a great role in the establishment of the students' cultural self-confidence and the establishment of the correct values [14]. The teaching materials should be written in a way that retains their own strengths. On the basis of retaining its own advantages and characteristics, the teaching materials should be prepared by drawing on the advantages of other countries in the preparation of teaching materials, so as to increase the breadth of knowledge in the teaching materials and broaden the students' comprehensive horizons.

Third, textbook writers need to emphasize engineering knowledge and focus on interdisciplinary integration [15].

Although the knowledge in the PEP is generally deeper than THE GMH, the proportion of knowledge at the level of strategic thinking in the GMH is higher than that in the PEP. From the smallest of artificial intelligence products to the largest of buildings, roads, and bridges, the integration of engineering as a STEAM end-use integration has made an unprecedented contribution to the development of human society. The basic elements and qualities of engineering, such as creativity, design, practice, and product, can effectively enrich the connotation and nurturing value of the basic education curriculum, provide the most direct support for students' innovative and practical ability and problem-solving ability, and provide a more effective way to realize the curriculum objectives, training objectives, educational policies, and educational ideals.

It is one of the main trends in the reform of quality education in primary and secondary schools in China to build an interdisciplinary comprehensive curriculum system by integrating the knowledge of engineering and other disciplines [16,17]. Engineering has a unique value in cultivating students' learning ability, thinking ability, and practical abilities, and the STEAM integration concept centered on engineering deserves special attention from curriculum and teaching material researchers.

5. CONCLUSION

Based on the STEAM education’s perspective, this study examined the intellectual breadth, depth, and integration of mathematical problems with respect to one-dimensional equations in two sets of curriculum materials: 7th Grade Mathematics from Chinese People's Education Publishing House (PEP) and California-Algebra 1 published by American Glencoe McGraw-Hill Publishing House(GMH) to explore whether there is convergence or divergence of knowledge content in Chinese PEP textbooks and American GMH textbooks, and the impact on the effectiveness of mathematics education.

Initially, the findings of the research found that PEP and GMH both reflect the concept of STEAM education and emphasize the integration of disciplines, focusing on the breadth of knowledge covered by the textbooks, with special emphasis on the integration of mathematics and science and technology. Although STEAM education is an imported term for China, this study found that its core concepts have permeated Chinese secondary school mathematics textbooks: emphasizing the articulation and integration of disciplines, Chinese textbooks, like those in the U.S., involve five subjects, including S, T, E, A, and M.

Although there are plenty of similarities in these three textbooks’ sets on linear equations in one variable, it still disparities.

Firstly, in terms of the breadth of STEAM knowledge, the focus of the two countries' textbooks is different, with Chinese PEP textbooks focusing on the history and environmental engineering, while American GMH textbooks are more diversified and cover a wider range of knowledge and cultural areas, reflecting the distinctive national characteristics of each country.

The knowledge of both PEP and GMH covers the knowledge of S, T, E, A, and M disciplines, which is in line with the concept of STEAM education, but there is a big difference in the focus on different disciplines. Compared with the PEP, the GMH covers a wider range of knowledge, which is richer in content, and more diversified in the specific disciplines covered, reflecting the multicultural compatibility of the U.S. as a distinctive national characteristic. However, the PEP emphasizes many areas that are not covered in the GMH, such as environmental engineering, sociology, and history. As a nation with a long history of harmonious coexistence between humans and nature and a strong humanistic heritage, the Chinese textbook's focus on humanistic history, environmental engineering, and their integration into the math textbook reflects the country's distinctive characteristics and demonstrates its unique superiority. To a certain extent, it shows that the arrangement of textbooks can also reflect the characteristics of a nation and vividly interpret the unique advantages and features of the country.

Secondly, in terms of the depth of STEAM knowledge, the overall depth of knowledge in Chinese PEP materials is deeper, and the depth of knowledge about engineering in the U.S. GMH materials is deeper than that in China.

In the GMH textbooks, a considerable part of the low-level materials, repeated simple equations and calculation exercises, are too mechanical, and cumbersome; while in the U.S. mastery of engineering knowledge, students are required to create new products or new methods through inquiry, the U.S. GMH textbook depth of knowledge of the E class design coincides with the concept of engineering, emphasizing the integration of the engineering disciplines to strengthen the students' sense of innovation, worthy of reference in the development of teaching materials. The design of the depth of knowledge in category E of the American GMH textbook coincides with the concept of engineering, emphasizing the strengthening of students' innovative consciousness in the integration of engineering disciplines.

Third, in terms of knowledge integration, the Chinese PEP textbook pays more attention to the integration of knowledge related to technical subjects in the mathematics textbook, while the American textbook pays more attention to the integration of engineering knowledge and art knowledge into the mathematics textbook, and pays attention to the cultivation of students' migratory thinking, and the textbooks of the two countries have their own focuses and strengths, which can be complemented with each other's strengths, and the content of the knowledge content of the mathematics textbook and the interdisciplinary paths can be enriched continuously.

CONSENT

As per international standards or university standards, respondents’ written consent has been collected and preserved by the author(s).

ETHICAL APPROVAL

As per international standards or university standards guideline participant consent and ethical approval has been collected and preserved by the authors.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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