Systematic Review of Technology-Based STEM Education Research during Teacher Education in the United States

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***Abstract* – This study conducted a literature review of technology-based STEM education research papers from 2015 to 2023. Data collection and analysis followed the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) checklist. In all, contents of 29 papers were analyzed. This study analyzed the research content of the two stages of pre-service and in-service teacher education and clarified the scope of research based on technology education content in research papers. The results demonstrated that, although the limited data failed to provide a unified reference framework, the data revealed existing research emphasizing the content of teacher education for K–12 and the importance of practice-related research for teacher self-efficacy and experience of best practices. In addition, the pre-service teacher education stage emphasizes the relevance of practice at the school stage and the research content of the transformation from theory into practice. The in-service teacher training stage has more diverse theoretical guidance and practical experience. Because of the opportunities provided outside the school, the position of technology education in the integration of STEM education is promoted more actively. Furthermore, these study results might provide a foundational reference for future related research.**

***Keywords* – Educational stages, in-service teacher, pre-service teacher, PRISMA, student-centered learning.**

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1. Introduction

With the emergence and development of science, technology, engineering and mathematics (STEM) education in the United States during the 19th century, research in the field produced numerous and cumulative achievements. They are presented more openly to the surrounding environment. Increasingly, researchers are devoting attention to methods based on student-centered learning, especially in the United States, where research on STEM education at all school levels (from early childhood education to higher education) has blossomed. Moreover, STEM education is evolving and expanding into various forms, with augmented classifications including science, technology, engineering, arts, and mathematics (STEAM), environmental education, science, technology, engineering, and math (E-STEM), and science, technology, robotics, engineering, art, and math (STREAM).

2. Literature Review

The first Handbook of Research on STEM Education, published in 2020, brings together the most relevant topics in the field over the past few decades [1]. It explains six major themes through more than 200 chapters. A key feature of this handbook is that it specifically examines integration of the STEM disciplines as the framework for STEM education work and research. Additionally, it presents examination of relevant policies from different countries engaging in STEM education and presents new questions at the end of the book to guide future research [1]. In summary, this book introduces STEM education to a wider audience through its historical, policy, and integrative framework.

Current research particularly emphasizes efforts to integrate the disciplines, but such integration is not always assigned equal weight [2]. The integrated STEM approach recognizes the role of technology and engineering in helping students deepen their understanding of the real world and their ability to effect change [3].

This approach uses design, science, and mathematics knowledge to facilitate this process. However, few studies have specifically examined details related to technology education. In 2024, Springer published the book ‘Locating Technology Education in STEM Teaching and Learning’, aimed at positioning technology education within STEM teaching [4]. This limitation might derive from the ambiguous integration content associated with technology education [4]. Furthermore, when technology education is incorporated into STEM, it is often perceived merely as using technological tools. to address science and mathematics learning needs.

The book author further argues that it was intended specifically to explore and clarify the definition of “T” in STEM educations, which is crucially important for understanding interdisciplinary integration. Moreover, the book presents an explanation of the central role of technology education in STEM education through seven key themes. The author argues that technology education enables students to apply their knowledge and skills to create practical solutions and technological products. Moreover, it offers extensive insights into various aspects of technology education, including the subject areas of technology and engineering, effective design teaching methods, and the importance of food, textiles, and maker spaces within STEM environments. Additionally, the book provides historical and philosophical background on technology education, discussing product or artifact development and outlining its constructivist theoretical foundation [4]. The book emphasizes the importance of technology as both an artifact and as a practical skill, highlighting the importance of traditional, implicit practices that cannot be conveyed through theory alone [4].

Although the manual provides detailed information about technology education in the Handbook of Research on STEM Education and Locating Technology Education in STEM Teaching and Learning, systematic trend research must be conducted to present a comprehensive overview of STEM education research based on technical education.

Two key points must be clarified. Given the characteristics of technology education in the US, it can be categorized into four main areas: general education, teacher education, vocational education, and professional education. Teacher education is a part of professional education that trains teacher candidates to organize general and vocational education within schools. It includes continuing education to help update skills after becoming a teacher. This study outlined and restricted the scope of technology education based on the criteria for data exclusion.

This study is a literature review of four categories of education separately and a summary of their four scopes after partial research, producing a general picture of the research at each stage based on different school levels and yielding a complete systematic summary of research trends.

Last year, a systematic literature review of technology-based STEM education was conducted at the general education stage. That review revealed that the content and evaluation types of technology education are becoming increasingly sophisticated. Digital technology is cited widely in teaching for its core role in technology education. Moreover, STEM education evaluation is no longer limited to assessment of knowledge and skills. Instead, it is based on other evaluation criteria that include learning motivation, and emotions. However, with the rapid development of technology, one must be careful to avoid introducing all technologies into the classroom simultaneously. Instead, it is necessary to awaken the enthusiasm for participating in subject integration through this experience and through broader exposure to technology [5]. Research related to teacher education has become necessary because of the importance of introducing STEM education. Actually, teacher education is the first key element for exposure and for increasing these contents in school education [6].

The section of the handbook addressing teacher education research introduces that elementary, middle, and K–12 stages are encouraging teachers to integrate their knowledge more and have a positive attitude, perceived ability, and confidence in STEM education, but technology education is evaluated together with engineering education. Additionally, it encourages leaders to experience STEM education professional development through professional practice communities, to use the collective efficacy of STEM in their teaching practices, to integrate disciplines, and to promote the teaching of STEM methods [1], [7].

Teacher education is divided into pre-service and in-service stages according to the phases of activity before and after becoming a teacher [8]. The two differ in their training contents, durations, and objectives. Still, the early stage is the foundation of the later stage. The last stage includes the deepening and continuation of earlier results.

Most current research investigating teacher education specifically examines one period. A detailed and systematic review, based on the technology education foundation but conducted at a more comprehensive level, is necessary.

3. Methodology

The first publication describing systematic evaluation was by [9], published in 1753, which reviewed all earlier publications on scurvy. Systematic reviews only appeared sporadically during the 1980s, becoming more common after 2000. Such reviews are used in the medical field, especially clinical practice and public health, with the purpose of using standardized methods for evaluating treatment effectiveness, patient health status, etc. With the development of psychology, measurement, and educational reform, more structured and systematic methods for evaluating student performance, teaching effectiveness, and educational outcomes have emerged gradually. The use of systematic evaluation in education began in the late 19th century, when standardized testing came into being and continued to develop throughout the 20th century, particularly addressing evaluation of educational programs, policies, and outcomes. By the mid-20th century, the field became more formalized and popularized along with the increasing importance of assessing and improving educational quality. The rapid development of information technology has brought new opportunities for systematic analysis in the field of education. It has promoted rapid growth of the method, expanding from simple quantitative analysis to complex multidimensional evaluation systems such as mixed analysis [10].

Unlike traditional or narrative literature reviews, which have been criticized as biased and arbitrary, systematic reviews are intended to be rigorous and transparent at each review process step, making them replicable and updatable. *“We should not look at any study in isolation, but at the body of evidence”* [11], to demonstrate systematically that existing research findings include arguments to shape and guide practice and policy [10].

The PRISMA statement is a reporting guideline published in 2009. It includes 27 checklists, each with supplementary reporting guidelines and reporting examples, guiding researchers in transparently reporting their systematic reviews [12]. The PRISMA statement includes steps, guidance, and suggestions for developing a protocol, defining search terms, outlining inclusion and exclusion criteria, and critically evaluating studies: A traditional sign of this approach’s “rigor” and “quality.” It also provides a simple list of points corresponding to each part of the review (e.g., title, conveying the type of review, and information sources, with names of all databases and search dates). Its purpose is to address difficulties of poor-quality reporting of systematic reviews. These recommendations have been widely recognized and adopted. The contents of the 2020 version have been upgraded.

Moreover, the checklist has been expanded to 41 items. It is more transparent and comprehensive than the earlier version. The PRISMA 2020 guideline provides mixed-method reporting standards for systematic reviews, including quantitative and qualitative studies [13].

The new version of PRISMA has greater transparency and standardization and emphasizes biases and limitations. This study therefore uses the latest version of PRISMA 2020 as a research guide.

4. Research Questions

The objectives of this study are as follows:

1) What is the scope of technology content in U.S. technology-based STEM education research of the teacher education stage during 2015–2023?

2) What are the contents and levels of technology-based STEM education research in the United States during the teacher training stage?

3) What are the contents and levels of technology-based STEM education research in the United States during professional development at the teacher stage?

5. Data Analysis

To ensure the consistency and comprehensiveness of the research, this study examined literature selected from four influential open-access databases in international academia, particularly in the field of education. These sources help ensure that the research covers a broad scope and that it has high quality.

5.1. Data Collection

The data for this study are sourced from the four most commonly used databases. Google Scholar is often the preferred search engine because of its accessibility and extensive data coverage. Over 80% of the academic papers in ERIC are education-related. Scopus and Web of Science are highly regarded for their authoritative peer reviews, comprehensive evaluation processes, indicators, and reports. Collectively, these databases offer a credible and thorough platform for conducting systematic reviews.

5.1.1. Search Strategy

To ensure a comprehensive and accurate search for initial identification of the literature, the keywords “STEM education,” “technology education,” and “teacher education” were used in various combinations according to the link syntax “or”. The aim is to capture all potential search results by rearranging the order of these three terms.

Next, the three keywords are linked using the conjunction "and", which helps narrow the search to literature that aligns closely with research focus. Furthermore, to provide a more comprehensive analysis of research related to STEM education, this study also substituted the keyword of STEM with STEAM, E-STEM, and STREAM to seek contents. In other words, this research encompasses data of various forms of STEM education studies.

To minimize bias, unpublished papers were also included. Moreover, the filtering criteria focused on literature published between 2015 and 2023. This timeframe is important because 2015 marked the passage of the STEM Education Act in the United States [14], signed into law by President Obama. This legislation represents a crucially important step for the United States government in fostering scientific and technological innovation, promoting economic growth, and advancing educational equity. The act was intended to enhance students' knowledge and skills in STEM fields through financial support, teacher training, and industry collaboration to address future social and economic challenges [1].

The initial screening identified 6,765 documents from four data platforms that fall within the scope of our study.

5.1.2. Data Filtering Criteria

Filtering criteria are presented in Table 1.

Table 1. Inclusion and exclusion criteria

Inclusion Criteria	Exclusion Criteria
Written in English	Not written in English
Studies available in full text	Studies unavailable in full text
Data attribution is correct	Data attribution error
No duplicate document was found in the other three databases	Duplicates of documents were found in three other databases
The study specifically examines the United States, distinguishing it from other mixed countries	Study regions in other countries outside of the United States
Study regions only of United States examined	Research does not emphasize the United States
Research areas involved in STEM/STEAM/STREAM / E-STEM education	Research areas outside of STEM/STEAM/STREAM / E-STEM education
Research is based on technology education	Research is not based on technology education
The research object is related to teacher education or professional development	The research object is not related to teacher education or professional development
The research content involved all the keywords	The research content only involves individuals or some of the keywords

Regarding the supplement to the Table 1, a more detailed explanation is presented along with the limitations based on technology education. In addition to being related to the content of technology education, and the technology education used for this study also limits the researchers' position, enabling a more precise definition of the technology component in STEM education research. Literature meeting the following three conditions will be included in the research scope; otherwise, the reports will be excluded. Final determination of the data was made by two authors separately. A consensus was reached.

Details are presented below:

1) The title includes the words "technology education."
2) Regarding co-authored works, at least one author belongs to a technology or engineering education department.
    - Educational technology, instructional technology, and learning technologies are not included.
3) Determine whether the author is related to technology education by reviewing their resume and work history.

- They have written a paper about technology education or engineering education.
- They belong to a technology-related academic society such as International Technology and Engineering Educators Association (ITEEA), Epsilon Pi Tau (EPT) - Epsilon Pi Tau is an international honor society for college students and professionals in technology. It recognizes students' academic achievements, preparation for work as a practitioner, and outstanding professionals. The Association for Career and Technical Education (ACTE) is an American professional organization active in career and vocational–technical education and established for supporting educational institutions and educators. It also specifically examines promotion of the importance of vocational and technical education, providing expert support to educators, and exploring ways to integrate technical and vocational skills into educational curricula.

5.2. Procedure

The PRISMA 2020 checklist, corresponding explanations and detailed information, and a flow diagram are vital reporting guidelines for systematic reviews. This study adhered strictly to the checklist for data screening.

Figure 1 presents an illustration of the change in the number of documents generated during the data screening process via a flow diagram, highlighting the number of records filtered out and those retained.

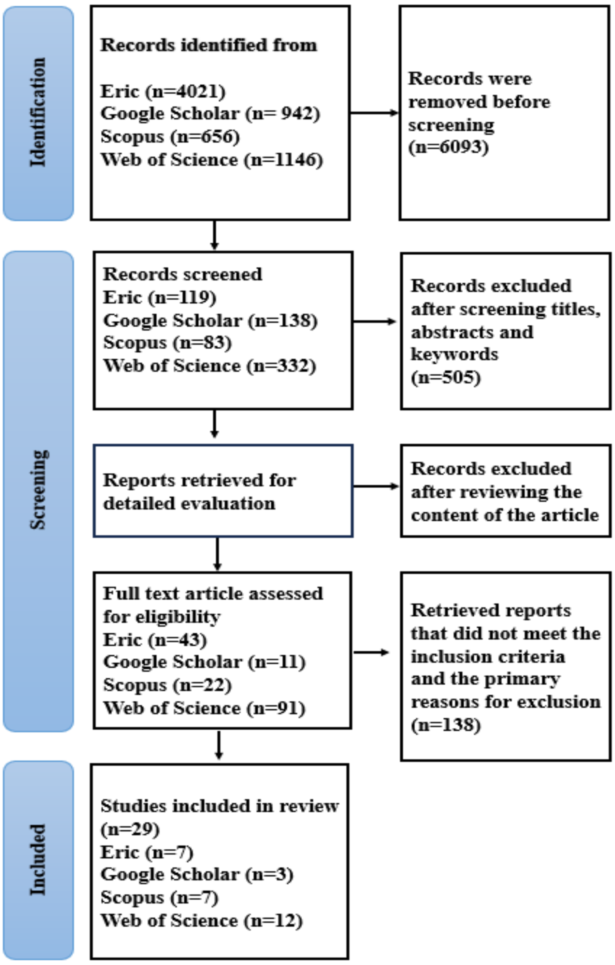

Figure 1. PRISMA flow diagram for data extraction

6. Results

This study analyzed 29 research papers and summarized the findings relevant to the research questions. Regarding research question 1, this study sought evidence related to the scope of STEM education research based on technology education in the field of teacher education. First, one must explain that the understanding of the scope of the study should be answered from two aspects:

The content relates to technology education in the study and the degree of mastery of the content by learners or the level at which the content is taught. The analysis results are presented in Table 2 and Table 3, as follows.

Table 2. Numbers of research studies of teacher education for school levels [15]

School level	Pre-service Teachers	In-service Teachers	Both pre-service and in-service Teachers
Higher education	4	0	0
Secondary education	9	9	6
Elementary education	10	6	2
Early child education	9	5	3

Note:
1. *This table was compiled using the statistical method of a gross number of studies. If a study is repeated at each school level, then the data are counted repeatedly.*
2. *Teacher education refers to research content related to teacher preparation and teacher training for university-level teacher candidates.*

Table 2 shows that research investigating technology-based STEM education is most extensive in pre-service teacher training. Specifically, the studies particularly addressing pre-service teachers numerically surpass those investigating in-service teachers. However, both categories are somewhat small: The former represents about one-third of the total in this area; the latter represents about half.

In terms of educational stages at school levels, the vertical summary shows that secondary education, encompassing middle and high school, has the highest volume of research. By contrast, the higher education stage shows the least amount of research. The numbers of early childhood and elementary education students are similar, but still lower than those in the secondary education stage.

Table 3 presents the classification of the research contents of technology education based on STEM education and the number of studies.

Table 3. Summary of research contents [16]

Research contents	Pre-service teachers	In-service teachers	Both pre-service and in-service teachers
Practice	3	6	3
Conceptual Framework and Practice	4	2	1
Theoretical Framework and Practice	3	1	3
Includes conceptual, theoretical, and practical frameworks	2	1	0

Table 3 shows that the numbers of studies on pre-service and in-service teachers are approximately equal. However, the total number of studies in both areas is not large, accounting for nearly half of the unilateral studies. Based on the content classification, most studies specifically examine practical applications. In contrast, studies related to conceptual frameworks and practices are equal in number to those examining theoretical frameworks and practices. Very few studies encompass all three aspects: practical applications, conceptual frameworks, and theoretical frameworks. These combined studies represent about one-fourth of the practical studies and approximately half of the studies specifically examining frameworks and practical applications. A clear explanation of the conceptual framework and the underlying theory is included as an additional description of this study.

The conceptual framework organizes the main concepts and elements used in a study and then presents their relations. Moreover, it provides partial elements without being based on theory.

The theoretical framework is based on existing theory, sets the research hypothesis, and provides a theoretical background. In other words, this framework provides a systematic reference for the study and a basis for theoretically interpreting the study results. Both play different roles in research progress.

The results of the pre-service and post-service research are that the theoretical framework mainly comprises the STEM integration framework, the Technological Pedagogical Content Knowledge (TPACK) framework, and self-efficacy. The theoretical framework integrates various disciplines based on STEM disciplines. The practical content integrates STEM education content and practice, as well as collective practice. Some studies have concluded that the factors and challenges of integrating STEM practices are that digital technology should not replace traditional game experiences. The key role of technology tools is to enhance children's game experiences with physical materials such as building blocks and puzzles in preschool environments. Some studies point out that improving PCK levels can enhance the understanding of technology, specific technology knowledge, and teaching methods, improve teacher–student interaction, improve learning outcomes and key decision-making capabilities, enhance teacher confidence, and promote student learning.

Table 2 and Table 3 present quantitative statistics related to the research questions. The scope of the research, as described in these questions, pertains to the analysis results, which include both the research content and the degree of teaching or mastery of research. A detailed summary and explanation of this content are provided respectively in research questions 2 and 3.

Table 4 presents a summary regarding research question 2.

Table 4. Contents and frequencies of STEM education research emphasizing technology education during the pre-service teacher stage [17],[18],[19]

School level	Practice	Conceptual framework and practice	Theoretical framework and practice	Conceptual and theoretical frameworks and practice
Higher education		TPACK + technology in their practice (1) Teachers' technology–integration belief + design practice (1)	industrial–social theory + hands-on practices (1)	designing for learning framework + experiential learning theory + VR-based micro teaching practices (1)
Secondary education	Robot practice (2)	P–12 T&E + STEL T&E practices//engineering contexts and practices (1) PCK of T&EEs + engineering contexts and practices (1) TPACK + technology in their practice (1)	industrial–social theory + hands-on practices (1) TPACK + combination of the content and practice of STEM disciplines (1) Both constructivism and constructionism/Vygotsky's Social Development Theory/Bandura's Social Learning Theory/Multimodality + community of practice (1)	TPACK + maker-focused constructionist framework + best practices for integrating CS (1)
Elementary education	Robot practice (2) the content and practices of technology/ engineering education (1)	P–12 T&E + STEL T&E practices//engineering contexts and practices (1) PCK of T&EEs + engineering contexts and practices (1) TPACK + technology in their practice (1)	industrial–social theory + hands-on practices (1) TPACK + combination of the content and practice of STEM disciplines (1) Both constructivism and constructionism/Vygotsky's Social Development Theory/Bandura's Social Learning Theory/Multimodality + community of practice (1)	TPACK + maker-focused constructionist framework + best practices for integrating CS (1)
Early childhood education	Robot practice (2)	P–12 T&E + STEL T&E practices//engineering contexts and practices (1) PCK of T&EEs + engineering contexts and practices (1) TPACK + technology in their practice (3)	industrial–social theory + hands-on practices (1) TPACK + combination of the content and practice of STEM disciplines (1) Both constructivism and constructionism/Vygotsky's Social Development Theory/Bandura's Social Learning Theory/Multimodality + community of practice (1)	TPACK + maker-focused constructionist framework + best practices for integrating CS (1)

Note:
1. *Numbers in parentheses show how many times the content appears.*
2. *PCK, pedagogical content knowledge; T&EEs, technology and engineering educators.*
3. *The term STEM in the table is a composite representation of STEAM, E-STEM, and STREAM research data.*

Arrangement of the contents of Table 4 is based on cumulative numbers. Therefore, the contents will be counted repeatedly, but it is apparent that some of the same research contents will extend from early childhood to the secondary stage. The content of each part has been connected until the secondary stage. In addition, Table 4 presents three readily apparent commonalities. First, the research assigns great importance to the practice part. No matter what stage and whether the framework is involved, it is related to practice. Second, whether it is a conceptual framework as a partial element or research as an overall theoretical framework, the TPACK framework is the most widely used.

Similarly, the construction theory is also used frequently in STEM education research. Third, the research content on practice is rich and colorful, including robot practice, design practice, hands-on practice, and a community of practice to create the best practice. Moreover, the evaluation level associated with these research contents has no unified standard. There are also many conclusions in the research content. However, it is apparent in the literature that the same technology education content will show consistent improvement as it progresses in the grade. The teacher group has no experience or confidence, but it has improved its self-efficacy in programming from the initial low level.

By participating in and observing student activities, they can see with their own eyes how students handle these materials, allowing them to know in advance what will occur when implementing the same materials in the classroom. Correspondingly, at the higher education level, pre-service teachers are helped to understand the rationale underlying the inclusion of technology in the STEM acronym, strengthening technology integration beliefs and scientific inquiry awareness through design practices.

The goal is for technologically adapted pre-service teachers to be able to use technology appropriately in their future classrooms without support and practice.

For research question 3, a summary is presented in Table 5.

Table 5. Contents and frequencies of STEM education research emphasizing technology education during the in-service teacher stage [20], [21],[22],[23],[24]

School level	Practice	Conceptual framework and practice	Theoretical framework and practice	Conceptual and theoretical frameworks and practice
Secondary education	Safety training practices (1) current concepts and hands-on practices in Industrial Robotics (1) Mathematical modeling practices (1) Science and engineering practices (1) Engineering design becomes a platform for STEM practice and learning in integrated STEM (1) Teachers and Researchers Advancing Integrated Lessons in STEM (TRAILS) (1) Community of practice (1)	Six Pillars conceptual framework + six processes that is useful to guide practices (1) TPACK and the TETCs + Practice Based Teacher Education (PBTE) (1)	Protocol's theoretical framework + science and engineering practices (1) Teachers' instructional practice (1)	Learning by design as a conceptual framework + constructionism theory + online educational robotics course for meaningful teaching practice and student learning (1)
Elementary education	Safety training practices (1) current concepts and hands–on practices in Industrial Robotics (1) Curriculum and instructional practices (1)	Six Pillars conceptual framework + six processes that is useful to guide practices (1) TPACK and the TETCs + Practice Based Teacher Education (PBTE) (1)		Learning by design as a conceptual framework + constructionism theory + online educational robotics course for meaningful teaching practice and student learning (1)
Early childhood education	Safety training practices (1) current concepts and hands-on practices in Industrial Robotics (1)	Six Pillars conceptual framework + six processes that is useful to guide practices (1) TPACK and the TETCs + Practice Based Teacher Education (PBTE) (1)		Learning by design as a conceptual framework + constructionism theory + online educational robotics course for meaningful teaching practice and student learning (1)

Note: Numbers in parentheses represent how many times the content appears.

The research specifically examines higher education that is not evident during the in-service teacher phase. In this stage, practical content is emphasized more than in other areas, especially within secondary schools. However, much of this emphasis revolves around teacher education and its practical applications.

The TPACK framework, which also applies to the teacher training phase, includes theoretical learning, group practice, and robotic practice. The key distinction is that safety practices and integrated STEM education practices are incorporated at this stage.

Additionally, a six-pillar framework is involved in the training process. The outer layer of this framework represents the overarching vision, which encompasses the purpose, priorities, and principles. The inner layer comprises six pillars: coordination and leadership, connectivity and infrastructure, cost and sustainability, capacity and culture, content and solutions, and data and evidence.

Moreover, the protocol's theoretical framework builds on the existing theoretical framework. It includes four dimensions: technology types, science and engineering practices (SEP), student-centered teaching, and relevance of the materials to students' lives.

There is no fixed reference standard for the pre-service teacher phase, but the evaluation of research content during this phase will specifically examine its applicability in teaching environments. This examination will involve using appropriate assessment technologies, including online management tools such as Google Classroom. In-service training will also include practical robotics experience, with corporate sponsorship opportunities. New robotics courses and equipment obtained through these partnerships will engage K–12 teachers and students while enhancing undergraduate learning.

The in-service teacher phase will prioritize integrating technology into a student-centered approach, fostering necessary modern skills and knowledge such as problem-solving, creativity, digital citizenship, logical thinking, curiosity, and innovation. The K–12 teacher workshop will introduce technological advancements to individuals who are crucially important in inspiring future engineers and technicians. Additionally, learners will be obligated to complete specialized courses in educational technology and technology education.

7. Discussion

This study was conducted to explain the contents and teaching level of research content on technology in STEM education research more comprehensively and systematically based on the research of technology education researchers. Furthermore, the findings reinforce results obtained from earlier studies.

1) Although technology education appears in the initial STEM education, its definition and position are not as clear as they are in other disciplines [25]. Additionally, it is easy to confuse the difference between educational technology and technology education at the moment of the rise of engineering [4]. Researchers of each discipline will put their discipline at the center of the integration. Technology is no exception. Technology education strengthens students' learning outcomes and the interaction between teachers and students in the classroom environment [26], [27].
2) Student-centered and real-world experience are essential features of STEM education [28]. Technology enables learners to participate in real-world tasks and to build knowledge by learning by doing, which is the premise of constructivist theory [29], [30]. In other words, constructivism advocates a student-centered environment [24], [31] to support the knowledge construction process and to provide opportunities for investigating, creating, and solving problems composed of real-world tasks [6], [32].
3) Teacher education plays a vital role in school education derived from STEM education. Teachers' experience and self-efficacy will affect the degree and extent of integration of technology education directly [7], [33]. Although no unified standard exists, constructivism theory, the guidance of the TPACK theoretical framework [34], [35], and collective practice among teacher groups are all important contexts. While filtering research data, it was also found that other disciplines have worked to construct a relation between educational content knowledge, method knowledge, and technical knowledge through the TPACK framework.
4) This study also supplemented earlier research investigating more practice contents of technology education [36]. In addition to the commonly used food, knitting, and manufacture, there are robots [28], [37], [38], [39], 3D printing [40], Virtual Reality (VR) [41] technology, hands-on technology, and other contents. Moreover, it enriched the content related to the framework. In addition to the conventionally valued construction theory and TPACK framework, teacher education must consider self-efficacy theory.

8. Conclusion

This study reviewed the research scope of STEM education systematically based on technology education, covering widely various topics from theoretical and conceptual frameworks to practical applications. The following findings can be presented.

1) Overall, research elucidating teacher education is concentrated mainly as addressing the K–12 stage. Although the numbers of studies of pre-service and in-service teachers are nearly equal, the number of studies examining teacher development is greater. The content specifically examines practical research. The theoretical and conceptual frameworks will also provide context for practice. In addition, research related to technology education content is aimed at better integrating STEM education practice.

2) Research content is available at the whole school stage (preschool to high school) in the pre-service stage. The research in this stage devotes greater attention to standard theoretical and conceptual frameworks such as the guidance on self-efficacy provided by various practices to teachers.
3) Some studies have examined the in-service teacher stage in the K–12 stage. The research content of this stage is richer and more diverse than that of teacher development. In fact, even in the same practical research, the influence of the social environment (corporate sponsorship, school policy) will be enhanced. More attention will be devoted to mutual communication and learning between teacher practice groups.
4) As a limitation of the research, based on the existing data, it remains impossible to provide a unified framework and evaluation criteria for STEM education based on technology education at the teacher education stage. Nevertheless, the results obtained from this study are expected to provide a fundamental reference for future attention and research in this direction. Technology education will likely play a more important role in the integration of STEM education.

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