International Journal of Technology and Design Education (2024) 34:1003–1044
https://doi.org/10.1007/s10798-023-09851-9

Assessing the state of technology education in primary schools: a systematic review of the last 2 decades

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Accepted: 31 August 2023 / Published online: 22 September 2023

Abstract

This study reports on a systematic review of the current status of technology education in primary schools and the terminology used in the fields of technology and engineering education. Additionally, this review highlights crucial aspects of teaching and learning that must not be overlooked when outlining the current state of technology and engineering education, such as students' and teachers' personal factors, classroom communication, and teacher professional growth. Following PRISMA guidelines, two electronic databases were reviewed, Web of Science and Education Resources Information Center. The literature search identified a total of 1206 papers, 125 from Web of Science and 1081 from ERIC. After applying the inclusion and exclusion criteria, 33 papers were selected and evaluated in depth. The results show that research on technology education in primary schools is a growing field of interest but fragmented in focus. Our review is the first to indicate the wide range of technology and engineering education definitions. We also highlight the large heterogeneity of studies focusing on students' and teachers' personal factors and classroom interactions, a finding that may be explained by the unclear concepts and aims of technology and engineering curricula. This study contributes to and supports research and policymaking to better understand the current status, heterogeneities, and challenges in technology and engineering education in primary schools. In addition, we provide first insights to support professional development efforts targeting teachers' technology acceptance and improvement of their technology-related teaching practices.

Keywords Technology education · Engineering education · Primary school teachers · Primary school students · STEM · Review study · PRISMA

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Introduction

The significance of technology is constantly growing with the swift technical-productive advancements in all spheres of society (Mammes et al., 2019). Usually, technology (T) and engineering (E) are less emphasized in STEM (science, technology, engineering, and mathematics) education compared to science (S) and mathematics (M) (Bozick et al., 2017). Additionally, technology education in primary schools typically focuses on computer science and informatics, while the technical and practical aspects of technology education are often overlooked (Davies, 2011; Firat, 2017; Wender, 2004).

Differences in the description of technology education exist at various levels of education, including primary schools, both across countries and within a country's provinces and districts (Keskin, 2017; Mammes et al., 2016; Rasinen et al., 2009; Williams, 2006). The lack of unified standards regarding the definition, status, content, aims, and pedagogical approaches in technology education presents multiple challenges to its effective implementation (Rasinen et al., 2009; Williams, 2006). In Germany, for instance, where education governance is decentralized, significant variations in curriculum subjects, structures, and content exist among federal states (Mammes et al., 2012, 2016).

Technology-related topics in the German curriculum fall under the category of "general science" based on the curriculum of each state (Mammes et al., 2016). Similarly, in the United States, the curriculum in primary schools can vary depending on the school district and state requirements (Sanders, 2009; Williams, 2006). Like Germany and US, a number of other European countries (such as Austria, Estonia, Finland, and France) were unable to successfully implement a standardized curriculum with common standards, objectives, and operational guidelines (Lavonen, 2021; Lee & Lee, 2022; Mammes et al., 2016; Rasinen et al., 2009). The subject of technology is often integrated into different subjects, such as "science and techniques" in France (Jones et al., 2013; Williams, 2006) and "craft and technology education" in Estonia (Rasinen et al., 2009). The blurred distinction between science, technology, and craft subjects may hinder students' technological competencies due to the lack of clear descriptions and operational instructions (Mammes et al., 2016; Rasinen et al., 2009; Williams, 2006). Additionally, distinguishing between technology and engineering poses challenges in terms of their aims and implementation process (Boeve-de Pauw et al., 2020; Rossouw et al., 2011).

Previous reviews have examined the status of STEM education, technology, and engineering education at higher educational levels. Reinholz et al. (2021) highlighted the lack of a clear and consistent theoretical framework for STEM subjects. Li et al. (2020) conducted a systematic analysis, finding that STEM education research is gaining global prominence, with distinct journals focusing on the field. Margot and Kettler (2019) identified perceived barriers among teachers and recommended collaboration opportunities and access to high-quality curriculum resources to enhance STEM implementation. Sherman et al. (2010) explored key issues related to technology education in middle schools.

Despite the inclusion of technology education in various countries' educational curricula, there is a need to establish a clear and consistent understanding of the subject (Pappa et al., 2023). Additionally, it is crucial to establish unified standards, goals, and guidelines for effectively implementing technology education in schools (Rossouw et al., 2011). To successfully define and understand the role of technology education, we first investigated the current status of technology education research, summarized and identified the definitions used in empirical studies from the past 2 decades. Additionally, the review includes studies that address key stakeholders in primary education, including teachers, students, and the classroom environment. Technology education holds the potential to enhance the development of personal factors for both students and teachers (e.g., Douglas et al., 2016; Post & van der Molen, 2014; Rohaan et al., 2010). Teaching and learning are intricate processes, and to comprehend and enhance technology education practices, it is crucial to examine all the essential teaching and learning parameters (Kilpatrick et al., 2001).

Teachers' and students' personal factors and technology education

Irregular educational standards in technology education might influence both students' and teachers' technical personal factors (i.e., beliefs, perceptions, competences, etc.) (Georgiou, et al., 2023b; Mammes et al., 2012; Möller et al., 1996) and teachers' lesson planning decisions (Georgiou, et al., 2023b; Mammes et al., 2016; Pappa et al., 2023). Competence and confidence are required for teachers in technical education (Davies, 2000; Möller et al., 1996; Pappa et al., 2023). It is essential for teachers to acquire a cohesive and clear understanding of the concept of technology so that they can foster positive student attitudes toward the subject (De Vries, 2000). Moreover, teachers' lack of training and technical expertise may affect their lesson planning and implementation and increase their resistance toward technical education (Mammes et al., 2016; Pappa et al., 2023; Rohaan, 2009).

Similar to teachers, students' technological skills and engagement with technology and engineering subjects may help them to connect their daily experiences with these subjects and enhance their critical thinking and problem-solving skills (Sneider & Ravel, 2021; Wright et al., 2018). Students' positive attitudes toward technology are often linked to an accurate and broader understanding of technology (Rohaan et al., 2010). Students who do not feel confident and competent in their technological abilities might neglect these subjects in their learning processes (Rasinen et al., 2009). More specifically, a lack of technological abilities can restrict students' opportunities and decisions regarding their educational options, such as university courses and vocational training (Mammes et al., 2012; Rohaan et al., 2010). Additionally, in early childhood, inadequate technical socialization may often lead to negative self-cognitions regarding technology and negative judgments about one's technical capabilities (Jakobs & Ziefle, 2010; Mammes et al., 2016). Thus, the development of technological education in primary school curriculum may foster teachers' personal factors related to technology implementation, increase students' interest in technology and science, and reduce the existing gender interest (i.e., gender stereotypes about male and female interest in STEM subjects) and motivational differences in STEM subjects (Mammes et al., 2016; Wright et al., 2018).

Aim of the study

Defining technology education is a critical issue in the teacher education literature, and it is not without controversy (Boeve-de Pauw et al., 2020; Rossouw et al., 2011). Technology education curricula and course descriptions are relatively diverse, and there is no common understanding and agreement about the aims and learning purposes of technology education (Sherman et al., 2010). The disciplines, definition, and understanding of technology education, in general, have often been interpreted similarly to engineering education (Rossouw et al., 2011). However, they have also been viewed as distinct subjects with different goals and aims (Koul et al., 2018).

This study adopts the terminology of technology education of Fox-Turnbull (2016) and Ropohl (1991) as the examination of the function of artifacts, design processes, and the evaluation of technological solutions within social and cultural contexts. The first aim of this literature review study is to examine how technology education in primary schools has been defined based on empirical studies from the past 2 decades. In addition to clarifying terminology, the study also seeks to investigate the extent to which empirical studies have focused on the personal factors of teachers and students, as well as the classroom environments that support effective technology education. To achieve this, a diverse array of topics, methodologies, and research designs are incorporated to examine the current research evidence. Specifically, the current literature review addresses the following research questions:

1. How is technology education in primary schools defined based on empirical studies from the last 2 decades?
2. To what extent do empirically based studies focus on students' and teachers' personal factors as well as classroom environments in primary school technology education?

The focus of this review is on primary school teachers, students, and classroom environments for several reasons. Firstly, technology and engineering education in primary education is often under-emphasized or only briefly addressed within other subjects, such as science (Mammes et al., 2016; Wright et al., 2018). Secondly, technology education has the potential to enhance the development of personal factors among both students and teachers (e.g., Douglas et al., 2016; Post & van der Molen, 2014; Rohaan et al., 2010). Thirdly, a lack of technology socialization in early school years may negatively impact students' competencies, future career choices, and gender stereotypes (Jakobs & Ziefle, 2010; Mammes et al., 2016).

Through the two aforementioned research questions, we seek to set the ground frameworks for the concepts and goals of technology and engineering curriculum, with implications for enhancing and developing teacher professional development (TPD) initiatives pertaining to technology education. These efforts are intended to positively impact students' perceptions, attitudes, and comprehension of the technology and engineering curriculum.

Method

Information sources and search strategy

A systematic literature review was conducted by searching for published articles between 2000 and 2020 in two widely recognized databases: Web of Science (WoS) Core Collection and Education Resources Information Center (ERIC). The selection of these databases was based on their reputation for containing peer-reviewed scientific and scholarly literature from various disciplines and regions worldwide. The search strategy was developed in consultation with a librarian and included the following terms: "technolog* educat*", "primary educat*", "primary school*", "elementary educat*", "elementary school*". After reviewing the syntax of each database with the support of the librarian a search string was generated (Table 1). Each term was searched individually in the databases and then in the advanced search in WoS Core Collection and the Search History in ERIC the terms "primary educat*", "primary school*", "elementary educat*", "elementary school*" were selected and combined with the demand OR. This search string was then selected and combined with the term "technolog* educat*" and the demand AND. The search string was

Table 1 Information source and search strategies

Information Source	Search strings and parameters
WoS Core Collection	1: “technolog* educat*” 2: “primary educat*” 3: “primary school*” 4: “elementary educat*” S: “elementary school*”) 6: #2 OR #3 OR #4 OR #5 7: #1 AND #6 Timespan: 2000-01-01–2020-12-31 Document type: Article, Review Article
ERIC	S1: “technolog* educat*” S2: “primary educat*” S3: “primary school*” S4: “elementary educat*” S5: “elementary school*”) S6: S2 OR S3 OR S4 OR S5 S7: S1 AND S6 Timespan:: 2000-01-01–2020-12-31 Document type: Journal Articles Language: English

refined by using additional parameters, such as a defined time frame, document type (articles, review articles), and language (English), and was limited to peer-reviewed articles to increase the credibility of the study. The final search in all databases was performed in January 2023.

Inclusion and exclusion criteria

In order to select and include the relevant articles for our research questions from the selected datasets specific inclusion (IC) and exclusion (EC) criteria were defined. The inclusion criteria were the followings: IC1: journal articles, IC2: the study is written in English, IC3: the study is peer-reviewed, and IC4: the study is not listed in another database. The exclusion criteria of the study were: EC1: the study is not conducted at primary school educational level, EC2: the study is not about technology/engineering/technical education, EC3: the study does not refer to primary school students or primary school in-service teachers.

Data collection and analysis

The current systematic literature review was conducted in five phases according to the PRISMA 2020 guidelines (Page et al., 2021). In the first phase, the initial literature was conducted in both electronic databases WoS ($n = 125$) and ERIC ($n = 1081$). Based on the inclusion (IC1, IC2, IC3) criteria, a total of 282 papers (52 papers from WoS and 230 from ERIC) were excluded because of the type of paper, language, and peer-review criteria. To check the duplicates (IC4) Microsoft Excel software was used and 72 papers were excluded. Additionally, regarding the exclusion (EC1, EC2, EC3) criteria, 623 papers were excluded as illegible by the database search engine categories, such as “High school education”, “Computer Science”, “Pre-service teachers” etc. To validate the accurate exclusion of papers based on the refinement categories of the database search engine, a researcher

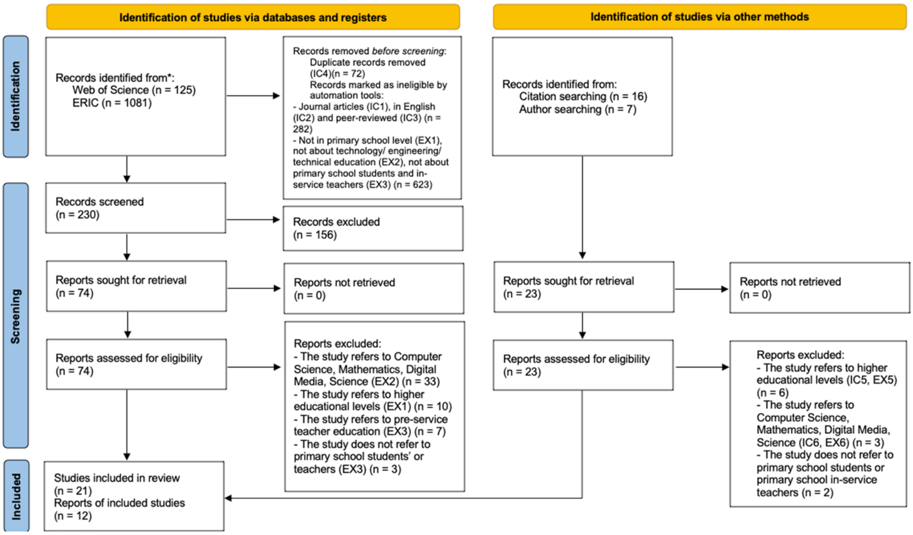

Fig. 1 PRISMA 2020 flow diagram

from our team conducted a rigorous review of the excluded papers. This comprehensive assessment was undertaken to ensure that no valuable paper was inadvertently omitted.

In the second phase, the title and the abstract of the remaining 230 papers were reviewed and the exclusion criteria (EC1, EC2, EC3) were applied. In case of insufficient information in the abstracts, the entire paper was browsed. This step resulted in 74 relevant articles for the review.

In the third step, the search results from this query were then used to retrieve the full-text articles. The resulting articles were reviewed independently by the first and the second author of this paper using the same inclusion and exclusion criteria and descriptors. The authors compared and verified their findings, and the degree of agreement was 95%. Disagreements were discussed until a consensus was reached. The first set of studies (n = 33) were excluded as they focused on topics outside the scope of the current review, such as computer science, mathematics, digital media, or science (EC2). The second set of studies (n = 10) were excluded as they were focused on higher education (EC1). Similarly, the third set of studies (n = 7) was excluded as they focused on pre-service teacher education (EC3). Finally, the fourth set of 3 studies was excluded as they did not involve primary school students or teachers (EC3). This method resulted in the exclusion of 21 articles due to the lack of fit to the predetermined criteria (Fig. 1).

In the fourth phase, to identify additional relevant publications, a manual search of reference lists of included studies and all their authors was conducted. This search resulted in 23 papers, which were thoroughly reviewed for relevance to the inclusion and exclusion criteria. In the fifth phase, the full text of the 33 papers was examined for relevance to the criteria and research questions of the current review. The described process is depicted in a PRISMA flow diagram (Page et al., 2021) (Fig. 1).

Additionally, to ensure the quality of the papers included in the review, two research experts from our team reviewed the selected articles regarding the Objectives and Purposes, Review of the Literature, Theoretical Frameworks, Participants, Methods, Results and Conclusions, and Significance. Because of the variety of studies, methods, and

Table 2 Quality evaluation rubric

Criterion	4 = Exceeds Standard	3 = Meets Standard	2 = Nearly Meets Standard	1 = Does Not Meet Standard
Objectives and Purposes	The study clearly states the problem, objectives, rationale, and research questions	Adequately stated	Poorly stated problem and rationale	Incomplete
Review of the Literature	Critically examines and situates the topic within the broader field, offering new perspectives and resolving ambiguities	The study effectively stated what has and has not been done in the field, situates the topic within the broader literature, and establishes connections to past work. It defines key vocabulary, synthesizes, and evaluates ideas	The literature review is limited and does not effectively synthesize or evaluate ideas	The article has incomplete or vague information about what has been done in the field, which creates gaps in the literature review
Theoretical Frameworks	The theoretical frameworks used in the study are well-aligned with its objectives, and the author provides a detailed explanation of them	The theoretical frameworks used in the study are well-stated and aligned with its purposes, contributing to its coherence and rigor	The theoretical framework is weak and does not align well with the study's purposes, leaving gaps or inconsistencies in the research design	Incomplete
Participants	The study offers a detailed and contextualized description of the population, sample, and sampling procedures	The description of population, sample, and procedures are stated	Brief description of sample and procedures	Incomplete
Methods	The instruments used and their administration are stated in detail, providing evidence for their validity and reliability and considering potential sources of bias	The instrument description is provided, evidence for their validity or reliability and considering potential sources of bias are described. Some evidence of best research practices is also documented	The instruments are described, but evidence for their validity or reliability is incomplete or lacking. Some questionable research practices may be present	Incomplete

Table 2 (continued)

Criterion	4 = Exceeds Standard	3 = Meets Standard	2 = Nearly Meets Standard	1 = Does Not Meet Standard
Results and Conclusions	The results are presented in detail and supported by effective data displays that connect the findings to past work and suggest avenues for future research	Complete and well-supported results. The discussion connects the results to past work and offers meaningful insights, while the conclusions address the problems or questions posed by the study	The results and discussion are basic, with insufficient use of data displays or analysis. The discussion fails to connect the findings to past work, providing little insight or perspective	Incomplete
Significance	Clearly and convincingly states the scholarly and practical significance of the study, addressing the problem or questions	The study clearly articulates the scholarly and practical significance of the study, highlighting its contributions to the field and potential applications in practice	Unclear or unconvincing articulation of scholarly or practical significance	Incomplete

Adapted from Mullet e al. 2017

research designs, each of the seven components was evaluated to determine if they met the standards for quality reporting, as outlined in Mullet's (2016) guidelines (Margot & Kettler, 2019; Mullet et al., 2017) (See Table 2). Each criterion was assessed using a 4-point scale, with a score of 1 indicating that the criterion did not meet the standard and a score of 4 indicating that it exceeded the standard. The total score for each article was between 7 and 28. Articles that scored 14 or less were considered to be of low quality and were excluded from the analysis. Articles with a score of 15 or above were included in this review. The assessment score of 15 out of 28 in our review was based on methodologies used in different peer-reviewed articles (e.g., Alangari, 2022; Davis, 2021; Margot & Kettler, 2019). Among the included articles, 10% scored between 15 and 19, 60% scored between 20 and 24, and the remaining 30% achieved scores ranging from 25 to 28.To ensure objectivity, in addition to the two research experts, the second author reviewed all 33 selected articles and confirmed that all retained articles met the quality criteria.

The final 33 articles were categorized into three groups based on the above-mentioned aspects for further analysis: definitions of technology education stemming from engineering and technology education (Group 1), technology education in primary schools for teachers and students (Group 2), and classroom practices (Group 3). A total of 22 articles were identified in Group 1, 24 in Group 2, and 9 in Group 3.

Analysis of articles

We designed a table (Table 3) to collect and organize the selected articles representing relevant aspects of each study. The table included information about the focus of each article regarding the study field (i.e., technology and engineering), study population (i.e., students, teachers, classroom environment), sample characteristics, the content of the study (i.e., which was the focus of the articles), research methodology, and the primary outcome. The first author read the full text of every article, identified the relevant aspects of each study, and completed the table. After completing the table, the second author randomly analyzed 30% of the selected articles (O'Connor & Joffe, 2020). Both authors independently compared their results.

The next step included the categorization of the content of each study into subcategories: (a) students' personal factors: beliefs/perceptions, knowledge/skills, attitudes, and students' group differences; (b) teachers' personal factors: beliefs/perceptions, knowledge/skills, attitudes, and teachers' TPDs; (c) both student and teacher data and classroom learning environment. The subcategories of students' personal factors and teachers' personal factors were selected based on previous studies indicating that knowledge and beliefs are strongly related and both contribute to teaching and learning procedures (Charalambous, 2015; Georgiou, Diery, et al., 2023a; Georgiou et al., 2020; Kilpatrick et al., 2001; Vermunt, 2005). Additionally, previous studies have demonstrated the strong interplay between personal factors, such as age, beliefs, knowledge, and attitudes, and contextual factors, such as the classroom environment, student–teacher interactions, and teacher instructions, in determining the learning experiences in a classroom setting (Vermunt, 2005).

As in the previous step of the analysis, the first author constructed a table for each group including the content and subcategories of each study: (Group 1), technology education in primary schools for teachers and students (Group 2), and classroom practices (Group 3) the table of the content and subcategories. Next, the second author analyzed randomly 30% of the chosen articles. Cohen's K was used to determine if there was agreement between two raters (Brennan & Silman, 1992; McHugh, 2012). The results revealed that there was excellent agreement between the two raters (K = 0.862 (95% CI 0.300 to 0.886), $p < 0.0005$).

Table 3 Examples of article summaries

Author and Year	Study field	Study population	Sample characteristics	Study location	Study content	Research methodology	Primary outcome
Boeve-de Pauw et al. (2020)	Technology	Students	• $n = 1496$ students • Age: 10–12 years old • Grade: 5 and 6	Belgium	• Students' attitudes after a technology intervention • Gender differences in the effect of the intervention	Quantitative longitudinal intervention study	• Short-term interventions could positively affect students' attitudes about technology • Interventions needed to be part of a broader boost STEM strategy • Highlight the importance of preliminary teacher workshop to influence the students' attitudes about technology
Capobianco et al. (2011)	Engineering	Students	• $n = 396$ students • Age: 6–11 years old • Grade: 1–5	United States	• Students' perceptions about what an engineer is • Gender, grade, and community differences	Mixed methods cross-age study design	• Students perceived an engineer as a mechanic, laborer, and technician who is fixing, building, and using tools • Students' conceptions did not depict big differences in urban and suburban communities • More than half of the students considered an engineer a male figure

Table 3 (continued)

Author and Year	Study field	Study population	Sample characteristics	Study location	Study content	Research methodology	Primary outcome
Fox-Turnbull (2016)	Technology	Classroom	• $n = 2$ teachers • $n = 12$ students • Age: 6 and 11 years old • Grade: 2 and 6	New Zealand	• Classroom technology educations and implications in teaching and learning	Qualitative ethnographic study	• Four stages of conversation to support classroom interactions in technology education: funds of knowledge, making connections and links, management of learning, and technology knowledge and skills
Post and van der Molen (2014)	Technology	Students Teachers	• $n = 22$ teachers • $n = 511$ students • Age: 11 years old • Grade: 5 and 6	The Netherlands	• Company visits impact students' images and attitudes towards technology and technical professions • Gender differences • Teacher interviews	Quasi-experimental mixed methods study	• No change in students' images and attitudes from the company visit • Teachers' involvement in the company visits could have an influence on the result
Rohaan et al. (2012)	Technology	Teachers	• $n = 354$ teachers • Grade: 3–6	The Netherlands	• Path model analysis of teacher knowledge domains, teacher knowledge, and attitudes towards technology	Quantitative path analysis study	• Teachers' subject matter knowledge is essential for PCK and self-efficacy • Teachers' self-efficacy could influence teachers' attitude about technology

Results

Description of technology education in primary schools

The first group of selected articles was used to answer the first research question and identify a definition of technology education. A total of 33 articles were selected, with 22 of them including definitions related to technology or engineering education. Among these articles, 12 focused on technology education, nine on engineering education, and one discussed both. As Table 4 illustrates, there is a degree of heterogeneity in how studies refer to technology and engineering education. In several articles, technology education was seen as part of the STEM courses or engineering or science. The study of Boeve-de Pauw et al. (2020) argues that technology education is not distinct from engineering education and can be interpreted as "Design and Technology" or "learning toward design technology". Hong et al. (2011) define technology education as the comprehension, construction, and development of artifacts and their functions. Milne (2013) emphasizes the importance of design and design processes in technology education, based on New Zealand's curriculum which includes the aspects of "Nature of Technology," "Technological Knowledge," and "Technological Practice". Another study that was located in New Zealand by Jones and Moreland (2004) defines technology education as the development of students' technological literacy by exploring and solving complex and related technological problems.

In Sweden, technology education is a mandatory subject aimed at developing students' technological competence and awareness (Sultan et al., 2020). The Swedish curriculum includes three aspects: a specific component, practical processes, and the relation to humans.

Studies based on the Australian national curriculum describe technology education as the purposeful application of knowledge, experience, and resources to create products and processes that meet human needs (Stein et al., 2002, 2007).

Firat (2017) differentiates technology from computer equipment and defines technology as the competence to understand and reason about technological artifacts and phenomena. Fox-Turnbull (2016) emphasizes the importance of conversation in learning and understanding technology.

Rohaan et al. (2010) emphasized that technology education should enable students to think critically about design, development, and implementation processes to solve practical problems. Solomonidou and Tassios (2007) defined technology as the process of dealing with crafts and human innovations to develop systems that solve problems and enhance human capacities. They highlighted the role of technology education and technological literacy in promoting technological knowledge and reasoning.

The connection between technology and engineering is highlighted in the study by Koul et al. (2018), which defined technology literacy as the understanding of designed procedures and tools, while engineering literacy involves understanding the improvement of technologies through design procedures. Both literacies are strongly connected and contribute to STEM literacy.

Various articles focused on engineering education, defining engineering and its aims based on the National Research Council (2012) and the Council (2013) (Cunningham & Kelly, 2017; Deniz et al., 2020; Douglas et al., 2016; Mangiante & Gabriele-Black, 2020; McFadden & Roehrig, 2019; Wendell & Rogers, 2013). Cunningham and Kelly (2017) described engineering as a collective enterprise that considers the affordances and constraints of the problem space, materials, and clients. Deniz et al. (2020) defined

Table 4 Group 1: Studies describing technology and engineering education in primary school

Number	Author and Year	Study field	Definition
1	Boeve-de Pauw et al. (2020)	Technology	Technology and engineering are connected. Technology education as “learning toward design technology” (p. 2)
2	Cunningham and Kelly (2017)	Engineering	“Engineering is typically a collective enterprise that requires consideration of affordances and constraints of the problem space, materials, and clients” (p. 306)
3	Capobianco et al. (2011)	Engineering	“Engineering education is to promote a technological and scientific citizenry that is knowledgeable about engineering and the work of engineers” (p. 307)
4	Davis et al. (2002)	Technology	Technology education is the “purposeful application of knowledge, experience and resources to create products and processes that meet human needs” (p.35)
5	Deniz et al. (2020)	Engineering	“Engineering is systematically engaging in the practice of design to achieve solutions for specific problems” (p. 638). Engineering education aim to engage students in design processes in order to find solutions to specific human problems
6	Douglas et al. (2016)	Engineering	Engineering as design related to scientific processes
7 8	English and King (2017), English et al. (2017)	Engineering	Engineering education as the development of design procedures
9	Firat (2017)	Technology	Technology understanding as an educational aim. The competence to understand and reason about technological artifacts and phenomena
10	Fox-Turnbull (2016)	Technology	“Technology education explicitly deals with the technological processes of investigating, designing, making and appraising technological solutions for identified problems or recognized opportunities within any given social and cultural context” (p. 22)
11	Hong et al. (2011)	Technology	Technology as project design. Understanding, constructing an artifact, and improving its functions
12	Jones and Moreland (2004)	Technology	Technology education refers to the development of students’ technological literacy by exploring and solving complex and related technological problems
13	Koul et al. (2018)	Technology Engineering	Technology literacy is the competence to apprehend the designed procedures and their tools and frameworks Engineering literacy is understanding the improvement of technologies by design procedures
14	Mangiante and Gabriele-Black (2020)	Engineering	Engineering education deals with the identification of an engineering problem, the development of solutions, and design processes

Table 4 (continued)

Number	Author and Year	Study field	Definition
15	McFadden and Roehrig (2019)	Engineering	Engineering as the engagement with practices that reflect the job of engineers, such as the definition of an engineering problem, its solution, and design processes
16	Milne (2013)	Technology	Technology education consists of “Nature of Technology,” “Technological Knowledge,” and “Technological Practice.” Engagement with these aims will lead to technological literacy. Technological practice leads to competence in design and design processes
17	Rohaan et al. (2010)	Technology	“Technology education should develop an understanding of the nature of technology, the relationship between technology and society, and technological design” (p. 16)
18	Solomonidou and Tassios (2007)	Technology	Technology refers to the process of dealing with craft and human innovation by developing systems in order to solve problems and broaden human capacities
19,20	Stein et al. (2002), Stein et al. (2007)	Technology	Technology education based on the national curriculum consists of four ‘strands’’: a ‘‘process’’ strand—Design, Make, Appraise—and three ‘‘content’’ strands -Materials, Information and Systems (p.36)
21	Sultan et al. (2020)	Technology	Technology education should develop students’ technological competence and awareness to operate in a technological world. Technology consists of three aspects, that is, it should obtain a specific component, practical processes, and be related to humans
22	Wendell and Rogers (2013)	Engineering	Engineering should provide students the opportunity to be part of scientific investigations in order to enhance their understating of design restrictions and solutions to a problem

engineering as systematically engaging in the practice of design to achieve solutions for specific problems. Douglas et al. (2016) related engineering to design processes connected to scientific processes. Mangiante and Gabriele-Black (2020) concluded that engineering education involves defining engineering problems, finding solutions, and engaging in design processes. McFadden and Roehrig (2019) and Capobianco et al. (2011) described engineering as engagement with practices that reflect the work of engineers. Wendell and Rogers (2013) investigated an engineering design-based curriculum, emphasizing engagement in design procedures to address constraints and find solutions.

The studies of English and King (2017) and English et al. (2017) highlighted the development of design procedures in early school years within engineering education. Their model of engineering design processes included problem scoping, idea creation, designing and constructing, design assessment, and redesign and reconstruction. These studies provide insights into the importance of design, problem-solving, and the connection between technology and engineering in technology education and STEM literacy.

Students' personal factors and group differences in technology education

The second group included articles on student and teacher technology education in primary schools. In this chapter, articles about students' personal factors and group differences in technology education were selected to address the first part of the second research question (Table 5).

Students' attitudes towards technology and engineering design-based science were examined in the studies of Boeve-de Pauw et al. (2020), Wendell and Rogers (2013), and Koul et al. (2018). Boeve-de Pauw et al. (2020) onducted a study on the impact of a short-term educational intervention on students' attitudes toward technology. The intervention positively influenced students' attitudes, particularly among female students who held stereotypical views about technology being for boys. Wendell and Rogers (2013) conducted a study on the impact of a short-term educational intervention on students' attitudes toward technology. The intervention positively influenced students' attitudes, particularly among female students who held stereotypical views about technology being for boys. Koul et al. (2018) developed an instrument to evaluate student attitudes in STEM classrooms, revealing some misconceptions among students about engineers. Male students showed an advantage in engineering and technology materials, while female students displayed better understanding of engineering concepts.

Capobianco et al. (2011), Davis et al. (2002), Slangen et al. (2011), and Solomonidou and Tassios (2007) discussed students' perceptions of technology and engineering. Capobianco et al. (2011) investigated students' perceptions of engineers, finding that students conceptualized engineers as mechanics, laborers, and technicians, often associated with male figures. Solomonidou and Tassios (2007) explored students' conceptions of technology, with some perceiving technology as modern tools and appliances while others emphasized its negative impact on the environment. The study conducted by Davis and colleagues (2002) examined students' understanding of technology concepts across different age groups, revealing both similarities and differences in their level of understanding. Slangen and colleagues (2011) studied students' understanding of robotics and found that problem-solving activities and teacher-led dialogue improved students' technological understanding and knowledge of robot functions.

The topic of students' knowledge and skills appeared to be most frequently discussed in the literature in terms of primary school students' personal competences (e.g., English &

Table 5 Group 2: Primary school students' personal factors in technology education

Number	Author and Year	Study field	Sample characteristics	Study location	Subcategory	Research methodology	Primary outcome
1	Boeve-de Pauw et al. (2020)	Technology	• $n = 1496$ students • Age: 10–12 years old • Grade: 5 and 6	Belgium	• Students' attitudes • Group differences	Quantitative longitudinal study	• Short-term interventions could positively affect students' attitudes about technology • The intervention contributed to reversing the female students gender stereotypical view that technology is mainly a topic for boys • Interventions needed to be part of a broader STEM strategy • Highlight the importance of preliminary teacher workshop to influence students' attitudes about technology
2	Capobianco et al. (2011)	Engineering	• $n = 396$ students • Age: 6–11 years old • Grade: 1–5	United States	• Students' beliefs/ perceptions • Group differences	Mixed methods cross sectional study design	• Students perceived an engineer as a mechanic, laborer, and technician who fixes, builds, and uses tools • Students' conceptions did not depict big differences between urban and suburban communities • More than half of the students thought of an engineer as a male figure
3	Davis et al. (2002)		• $n = 92$ students • Age: 6–13 years old • Grade: 2, 4, 6	Australia	• Students' beliefs/ perceptions	Qualitative interview study	• There are similarities and differences observed in students' understandings of selected technology concepts within and between the different age groups
4	English and King (2017)	Engineering	• $n = 69$ students • MAge: 9,23 years old • Grade: 4	Australia	• Students' knowledge/ skills	Qualitative longitudinal study	• Framework of engineering design processes in early education • Four design levels were identified from students' sketches • Students use of gestures assist them in problem scoping and generating ideas

Table 5 (continued)

Number	Author and Year	Study field	Sample characteristics	Study location	Subcategory	Research methodology	Primary outcome
5	English et al. (2017)	Engineering	• $n = 136$ students • *M*Age: 11 years old • Grade: 5 and 6	Australia	• Students' knowledge/ skills	Longitudinal mixed methods study	• Engineering techniques were observed in half of the initial sketches. The labeling of shapes and addition of materials and costs were less common • The independent school students were effortlessly able to express the correct usage of engineering techniques • Students practiced their problem solving and their design and guiding processes • Students used several problem components at the same time, showing their skills in working on complex tasks
6	Firat (2017)	Technology	• $n = 239$ students • Age: 10–12 years old • Grade: 5 and 6	Turkey	• Students' knowledge/ skills • Group differences	Survey mixed methods study	• Students depict a moderate level of recognition of technological artefacts • Socioeconomic status could affect students' technology recognition • Electricity was often associated with technology
7	Hong et al. (2011)	Technology	• $n = 4$ students • Age: 12 years old • Grade: 7	Taiwan	• Students' knowledge/ skills	Portfolio analysis qualitative study	• Students were actively participating with deep reflection in the technical process and construction of the artifact • Students' collaboration in the POWERTECH project was achieved by exchanging knowledge and resources among the students • The design process initiated problem-solving reflections, which led to fewer mistakes during the contest

Table 5 (continued)

Number	Author and Year	Study field	Sample characteristics	Study location	Subcategory	Research methodology	Primary outcome
8	Koul et al. (2018)	Engineering Technology	• $n = 1095$ students • Age: 9–12 years old • Grade: 4—7	Australia	• Students' attitudes • Students' knowledge/ skills • Group differences	Pre-posttest design quantitative study	• The validity of an instrument of students' classroom cooperation, involvement, and career interest in engineering and technology activities • Student career interest and understanding changed after the implementation of the activities • Male students shown an advantage in engineering and technology materials in the cooperation results and female students in engineering understanding
9	Looijenga et al. (2020)	Technology	• $n = 49$ students • Age: 9–12 years old	The Netherlands	• Students' knowledge/ skills	Qualitative case study	• Well-designed tasks were helpful initiators of engagement which resulted in well-considered design and products • Dialogue promoted the participation of unengaged students • Improvement of teacher-student and student–student relationships
10	Mammes (2004)	Technology	• $n = 90$ students • Age: 8 years old • Grade: 3	Germany	• Group differences	Quasi-experimental mixed methods study	• Male and female students' technological interest was awakened • Male and female students' differences related to dealing with technological objects were decreased • Technological interest, level of knowledge, and orientation were increased for both girls and boys

Table 5 (continued)

Number	Author and Year	Study field	Sample characteristics	Study location	Subcategory	Research methodology	Primary outcome
11	Milne (2013)	Technology	• $n = 10$ students • Age: 5 years old • Grade: 1	New Zealand	• Students' knowledge/ skills	Qualitative exploratory study	• Technology education is feasible and beneficial for 5-year-old students • The suggested strategies could assist students in understanding and reflecting on technological methods • Positive conceptual, procedural, technical, and societal outcomes
12	Slangen et al. (2011)	Technology	• $n = 12$ students • Age: 11–12 years old	The Netherlands	• Students' beliefs/ perceptions	Qualitative study	• The problem-solving activities and the support of the scaffolding dialogue with the teacher helped students to develop their technological perspective and understanding of the function of robots
13	Solomonidou and Tassios (2007)	Technology	• $n = 60$ students • Age: 9–12 years old • Grade: 4—6	Greece	• Students' beliefs/ perceptions	Interview Qualitative	• Most students associated technology with modern tools and appliances • Experience-based technologies were not often identified by the students as technology oriented • Daily-life technologies were identified either as technology oriented or human oriented • Students had difficulties with the concept of technological change
14	Sultan et al. (2020)	Technology	• $n = 5$ students • Age: 9–12 years old	Sweden	• Group differences	Ethnographic qualitative study	• Despite the gender-neutral activities, the female students verified the existing male patterns and conceptions about being technical • In situations where boys took over while working in the activity, female students expressed their dissatisfaction • Female students chose to work with materials and tools they considered more feminine

Table 5 (continued)

Number	Author and Year	Study field	Sample characteristics	Study location	Subcategory	Research methodology	Primary outcome
15	Virtanen et al. (2015)	Technology	• $n = 281$ students • Age: 11–13 years old • Grade: 5 and 6	Finland	• Group differences	Quantitative survey study	• Female students were more interested in studying environment related topics and creating home decorative artefacts • Male students enjoyed more building electronic devices • Male students were more confident than female students
16	Wendell and Rogers (2013)	Engineering	• $n = 245$ students • Age: 11–13 years old • Grade: 3 and 4	United States	• Students' attitudes • Students' knowledge/ skills	Quasi-experimental quantitative study	• The LEGO engineering students showed development in their science content achievement • Students' attitudes differed slightly between the LEGO engineering and status quo students • Design-based science curriculum units could help to improve students' science content knowledge

King, 2017; English et al., 2017; Firat, 2017; Hong et al., 2011; Koul et al., 2018; Milne, 2013). Milne (2013) found that project-based learning helped students develop technological knowledge and skills, as evidenced by their understanding of the purpose of a photo frame, creation of design plans, and reflection on emotions. English et al. (2017) examined students' STEM knowledge and design problem-solving skills, finding variations in engineering techniques and problem components between different schools In another study, English and King (2017) investigated students' skills and design processes in a civil engineering task, identifying the importance of content knowledge and gestures in problem-solving.

The aspect of communication and collaborative learning in technological project design was explored by Hong et al. (2011), who found that collaborative learning enhanced students' participation, reflection, and problem-solving during the design process. Looijenga et al. (2020) found that well-structured tasks and dialogue improved student engagement and relationships.

Firat (2017) examined students' recognition and reasoning skills regarding technological artifacts, highlighting moderate levels of recognition and associations of electricity with technology. Socioeconomic factors influenced students' technology recognition. Students' differences and more specifically gender differences were addressed in the studies of Mammes (2004), Sultan et al. (2020), and Virtanen et al. (2015). Mammes (2004) observed increased technological interest and reduced differences in dealing with technological objects among male and female students. The study of Sultan et al. (2020) found that despite gender-neutral activities, female students adhered to existing gender stereotypes and expressed dissatisfaction when males dominated activities. The research conducted by Virtanen and colleagues in (2015) discovered gender differences in preferences for environmentally-focused topics and decorative items among female students, while male students showed a preference for building electronic devices and reported higher self-assurance in their abilities.

Teachers' personal factors in technology education

This chapter discussed teachers' personal factors based on eight selected articles, addressing the second part of the second research question (Table 6). Four articles included a TPD on technology education and reported the results on teachers' factors (Deniz et al., 2020; Stein et al., 2000, 2007; Watkins et al., 2021). Deniz et al. (2020) examined the changes in teachers' engineering views after a 3-day TPD. Their study found that precise and reflective strategies should be included in engineering design experiences. Teachers' nature of engineering views (NOE) was improved after the TPD, and above all NOE aspects, their views regarding engineering design processes were more informed.

Watkins et al. (2021) studied the reasoning of two teachers about teaching engineering design processes following a teacher education program. Changes in the teachers' reasoning reflected both context sensitivity and growing stability.

Stein et al. conducted several studies on teachers' beliefs and understandings of technology education. In their first study (2000), they found that teachers related the meaning of technology to other learning areas already included in their teaching programs. In a later study (Stein et al., 2002), they investigated teachers' beliefs on implementing design and technology education practices, highlighting the impact of prior beliefs, experiences, and limited knowledge on teaching the subject. Finally, in a third study (Stein et al., 2007), they

Table 6 Group 2: Primary school teachers' personal factors in technology education

Number	Author and Year	Study field	Sample characteristics	Study location	Subcategory	Research methodology	Primary outcome
1	Deniz et al. (2020)	Engineering	• $n = 30$ students • Grade: 2 and 3–5	United States	• Teachers' views • TPD	Pre-posttest mixed methods study	• After a 3-day TPD program teachers improved their nature of engineering views (NOE) • Above all the NOE aspects, teachers' NOE views regarding engineering design processes were more informed • Precise and reflective strategies should be included in engineering design experiences
2	Jones and Moreland (2004)	Technology	• $n = 18$ teachers • $n = 2$ principles • Grade: 1–8	New Zealand	• Teachers' knowledge/skills	Qualitative case study	• The strategies that helped teachers to improve their PCK were: reflect on their own and on their colleagues' classroom practices case studies, use a planned framework, discuss interventions in the classroom, participate in workshops, provide classroom support, participate in agreement meetings, use student portfolios and summative profiling

Table 6 (continued)

Number	Author and Year	Study field	Sample characteristics	Study location	Subcategory	Research methodology	Primary outcome
3	Moreland and Jones (2000)	Technology	• $n=9$ teachers • Grade: 1–6	New Zealand	• Teachers' knowledge/skills	Qualitative case study	• Teachers' assessment practices were influenced by existing subcultures in schools, school policies and subject expertise • Learning and formative assessments were not focused on students' technological understanding but on general skills
4	Rohaan et al. (2012)	Technology	• $n=354$ teachers • Grade: 3–6	The Netherlands	• Teachers' knowledge/skills	Path-model quantitative study	• Teachers' subject matter knowledge (SMK) is essential for pedagogical content knowledge (PCK) and self-efficacy • Teachers' self-efficacy could influence teachers' attitudes about technology • Teachers seemed to acquire a basic level of SMK but a relatively low level of PCK

Table 6 (continued)

Number	Author and Year	Study field	Sample characteristics	Study location	Subcategory	Research methodology	Primary outcome
5	Stein et al. (2007)	Technology	• $n=4$ teachers • Grade: 7	Australia	• Teachers' beliefs/perceptions • TPD	Qualitative interview study	• The TPD helped teachers to express their ideas about technology education and articulate better their questions • All four teachers were more confident on teaching the content after the TPD
6	Stein et al. (2000)	Technology	• $n=2$ teachers • Grade: 4 and 5/7	Australia	• Teachers' beliefs/perceptions • TPD	Qualitative case study	• Two teachers' examples of technology implementation in classroom • Teachers' perceptions of technology developed through the study • One of the teachers in the study, improved his ability to communicate his thoughts on technology and technology education as the study progressed • The second teacher, recognized and acknowledged that students have varied learning styles, including auditory, visual, and oral

Table 6 (continued)

Number	Author and Year	Study field	Sample characteristics	Study location	Subcategory	Research methodology	Primary outcome
7	Stein et al. (2002)	Technology	• $n = 3$ teachers • Grade: 4, 6 and 5/7	Australia	• Teachers' beliefs/ perceptions	Qualitative case study	• The three teachers did not capitalize to help and evaluate students' learning and understanding • Teachers' prior beliefs, experiences and limited knowledge about design and technology found to be reflected on their lessons • The study highlighted how these teachers were able to utilize opportunities to improve their teaching practices and support their students' development

Table 6 (continued)

Number	Author and Year	Study field	Sample characteristics	Study location	Subcategory	Research methodology	Primary outcome
8	Watkins et al. (2021)	Engineering	• $n=2$ teachers • Grade: 3 and 5	United States	• TPD • Teachers' knowledge/skills	Qualitative case study	• Two teachers' reasoning about teaching engineering design processes • Changes were identified in both teachers' (STEM leader and science teacher) reasoning about teaching the design processes • Both teachers gained a deeper comprehension of the iterative nature of the EDP and were able to articulate it more effectively

explored teachers' experiences in a TPD program, noting that it helped them express ideas, ask better questions, and increase confidence in teaching technology.

Rohaan et al. (2012) examined teachers' knowledge domains in technology education and their relationship. The study found that subject matter knowledge (SMK) was essential for pedagogical content knowledge (PCK) and self-efficacy, with self-efficacy influencing teachers' attitudes toward technology. However, teachers had a relatively low level of PCK despite acquiring a basic level of SMK.

Moreland and Jones in (2000) explored the impact of teachers' technology classroom assessment practices, noting that these practices were influenced by school culture, policies, and subject expertise. Lack of technology-related knowledge hindered assessment practices, with a focus on general skills rather than students' technological understanding. In a subsequent study, Jones and Moreland in (2004) examined the use of frameworks and tools to enhance teachers' pedagogical content knowledge (PCK), identifying strategies such as reflecting on practices, utilizing frameworks, participating in workshops, providing support, and using student portfolios.

Teacher–student interactions and the classroom environment in technology education

The third group included articles regarding teacher–student interactions and the classroom environment in technology education (Table 7). In this chapter, nine articles were selected to address the third part of the second research question. Four studies focused on the classroom environment in engineering and technology education (Björkholm, 2014; Cunningham & Kelly, 2017; Fox-Turnbull, 2016; McFadden & Roehrig, 2019). Björkholm (2014) evaluated technical solutions in technology classrooms, finding that group discussions improved students' ability to assess suitability for purpose. Cunningham and Kelly (2017) examined classroom discourse in an engineering class, highlighting the development of communal knowledge and students' agency. McFadden and Roehrig (2019) analyzed instructional discourse strategies in engineering design activities, emphasizing the importance of pedagogical support processes. Fox-Turnbull (2016) identified stages of conversation in technology education and found that prior learning aided current learning processes.

Several studies reported data on teacher and student personal competencies, their influences, and interactions. Douglas et al. (2016) studied the implementation of engineering through a TPD program, noting variations in school support and time constraints. Mangiante and Gabriele-Black (2020) discussed the outcomes of TPD on teachers' implementation of engineering design curriculum practices and students' misunderstandings. Lottero-Perdue and Lachapelle (2020) examined students' general and engineering mindsets, observing differences based on socioeconomic status and the predictive power of general mindset.

Post and van der Molen (2014) investigated the effect technology-oriented company visits on students' attitudes and competencies, with limited changes observed and teacher involvement affecting the outcomes. In a review, Rohaan et al. (2010) the connection between teachers' technology knowledge and students' attitudes, highlighting the importance of teachers' PCK in fostering positive attitudes and influencing students' learning and interest in technology.

Table 7 Group 3: Primary school teacher–student interactions and classroom environment in technology education

Number	Author and Year	Study field	Sample characteristics	Study location	Subcategory	Research methodology	Primary outcome
1	Björkholm (2014)	Technology	• $n = 49$ students • Age: 7–8 years old • Grade: 1 and 2 • $n = 4$ teachers	Sweden	• Classroom	Phenomenographic qualitative study	• The collective discussions were meaningful in making students aware of materials and functions and how to evaluate technical solutions • A higher complexity was observed on students' skills to evaluate technical solutions in fitness for purpose
2	Cunningham and Kelly (2017)	Engineering	• $n =$ one school, around 800 students • $n = 1$ teacher	United States	• Classroom	Qualitative ethnographic study	• The teacher provided a common focus as a start for discussions and results comparisons • Students in groups work on the tasks and presents their results to the classroom, and communal knowledge was achieved • Students develop agency in order to take responsibility for their actions and relate more to the job of an engineer

Table 7 (continued)

Number	Author and Year	Study field	Sample characteristics	Study location	Subcategory	Research methodology	Primary outcome
3	Douglas et al. (2016)	Engineering	• $n = 10$ teacher • Grade: 2–4	United States	• Teachers' attitudes • Teachers' knowledge/skills • TPD • Teachers' support • Students' knowledge/skills • Students' perceptions	Case study mixed methods study	• Time was a restricting factor in planning and implementing an engineering lesson • Teachers' perceived level of school support varied among schools, although the TPD had district-level administrative support • Teachers' collaboration was identified as a valuable tool in the implementation of engineering lessons • Teachers did not express negative attitudes toward engineering education despite the challenges • Students experienced improvement in engineering, science, and technology in both years • Students' perception of the job of engineers was only enhanced in the first year

Table 7 (continued)

Number	Author and Year	Study field	Sample characteristics	Study location	Subcategory	Research methodology	Primary outcome
4	Fox-Turnbull (2016)	Technology	• $n = 2$ teachers • $n = 12$ teachers • Age: 6 and 11 years old • Grade: 2 and 6	New Zealand	• Classroom	Qualitative ethnographic study	• Four stages of conversation to support classroom interactions in technology education: funds of knowledge, making connections and links, management of learning, and technology knowledge and skills 5Students used and applied the knowledge gained in the learning processes • Prior school-based learning assisted students' and teachers' current learning processes during technology practices • Students were able to make connections to previous technology learning units • During their engagement, students were able to develop knowledge of technological practices and theory

Table 7 (continued)

Number	Author and Year	Study field	Sample characteristics	Study location	Subcategory	Research methodology	Primary outcome
5	Lottero-Perdue and Lachapelle (2020)	Engineering	• $n = 63$ teachers • $n = 2.086$ students • Age: 10–11 years old • Grade: 5	United States	• Students' mindsets • Group differences • Teachers' perceptions	• Experimental mixed methods study	• Students that scored higher for general mindset (GM) had higher engineering post-assessment results • Differences were observed in students with higher socio-economic status in their growth-minded engineering mindset (EM) scores • Students general and domain-specific EMs seemed to be very similar. GM was identified as a strong predictor of EM

Table 7 (continued)

Number	Author and Year	Study field	Sample characteristics	Study location	Subcategory	Research methodology	Primary outcome
6	Mangiante and Gabriele-Black (2020)	Engineering	• $n = 13$ teachers • $n = 279$ students • Age: 8–12 years old • Grade: 3 and 7	United States	• Teachers' beliefs/perceptions • TPD • Students' beliefs/perceptions	Qualitative multiple case study	• Students' conceptions of the work of mechanical engineers • Teachers identified misunderstandings in students' conceptions about engineers' job, subject language, functional design systems, and epistemic processes • In-depth TPD may be valuable to the implementation of engineering design curriculum practices • Teachers noticed that some students could make connections between the design idea and its effect, while others could not, and their writing about the design and the process of problem solving was unclear

Table 7 (continued)

Number	Author and Year	Study field	Sample characteristics	Study location	Subcategory	Research methodology	Primary outcome
7	McFadden and Roehrig (2019)	Engineering	• $n=1$ teacher • $n=4$ students • Age: 9–10 years old • Grade: 4	United States	• Classroom	Exploratory qualitative case study	• Examples of instructional discourse strategies in engineering design activities • The study highlighted the importance of designing and executing pedagogical support processes to assist students' perception of their designs and their use • Students were motivated to convince their peers in situations of uncertainty • Students were able to propose solutions because they felt at ease

Table 7 (continued)

Number	Author and Year	Study field	Sample characteristics	Study location	Subcategory	Research methodology	Primary outcome
8	Post and van der Molen (2014)	Technology	• $n = 22$ teachers • $n = 511$ students • Age: 11 years old • Grade: 5 and 6	The Netherlands	• Students' attitudes • Group differences • Teachers' beliefs/perceptions	Quasi-experimental mixed methods study	• Almost no change in students' images and attitudes from the company visit • Teachers' involvement in the company visits could have influenced the result • No interaction effects were identified regarding differences in gender, grade level, expected high9school entry levels, or general technology teaching performance in schools • Teachers were mostly involved with the company visit logistics and had some difficulties identifying the purpose of the visits or understanding their position as contributors to the program

Table 7 (continued)

Number	Author and Year	Study field	Sample characteristics	Study location	Subcategory	Research methodology	Primary outcome
9	Rohaan et al. (2010)	Technology	• 10–12 year old students	The Netherlands	• Students' attitudes • Teachers' knowledge/skills	• Content Analysis—Review	• Teachers' Pedagogical Content Knowledge (PCK) is necessary for students' positive attitude about technology education • Teachers' PCK could influence students learning and interest in technology • Six parameters of teachers' technology knowledge could influence students' attitude: general subject matter knowledge, concept of subject, knowledge of students' conceptions, knowledge of pedagogical approaches, knowledge of nature of subjects, and attitude

Discussion

The results of our literature review spanning from 2000 to 2020 indicate that technology and engineering education is a growing area of interest as evidenced by the increasing number of publications in recent years. Our study provides a thorough overview of how technology education in primary schools has been defined based on empirical studies from the past 2 decades. Alongside clarifying terminology, the review examines the extent to which empirical studies have emphasized the personal factors of teachers and students, as well as the classroom environments that promote effective technology education. These findings offer valuable insights into the current state of technology education in primary schools and the implications of the research for future practice and policy.

Our study reveals that little research has addressed the topic of technology education in primary schools without focusing on the aspects of computer science and informatics. As the article analysis pointed out the majority of the excluded studies were related to computer science, mathematics, digital media, or science (EC2). In addition, some studies were excluded because they were focused on higher education (EC1), and pre-service teacher education (EC3) or they did not refer to primary school students or teachers (EC3).

Technology and engineering are often mentioned in studies regarding science and STEM but not as distinct subjects with concrete aims and learning contexts (Keskin, 2017; Mammes et al., 2016; Rasinen et al., 2009). Various studies have highlighted significant differences in the technology education curriculum at different levels of education, including primary schools (Jones et al., 2013; Rasinen et al., 2009; Williams, 2006). These differences are not only apparent among different countries but also within the same country, making it challenging to implement technology education successfully (Mammes et al., 2016; Rasinen et al., 2009; Williams, 2006). The lack of unified standards, including the definition, status, content, aims, and pedagogical structures, further complicates the situation (Williams, 2006). Additionally, since there are no clear concepts and aims of technology and engineering curriculum, primary school teachers may not have the appropriate preparation or confidence to teach technological subjects (Georgiou et al., 2023b; Mammes et al., 2016; Pappa et al., 2023).

An analysis and synthesis of studies on engineering and technology education revealed that the terms "technology" and "engineering" sometimes overlap but have distinct emphases. As Table 4 illustrates, there is a degree of heterogeneity in how studies refer to technology and engineering education. Koul et al. (2018) defined technology literacy as the capacity to comprehend the design process, its tools, and frameworks. In contrast, engineering literacy is defined as an understanding of how technology is enhanced through the design process. However, other studies have argued that technology and engineering are interconnected and cannot be easily distinguished from each other (Boeve-de Pauw et al., 2020; Rossouw et al., 2011).

Based on previous research and the findings of this review, it is evident that technology and engineering education are interconnected. Both fields focus on understanding the design and operational processes, as well as the tools and methodologies used to develop and assess problem-solving solutions (Boeve-de Pauw et al., 2020; Fox-Turnbull, 2016; Rossouw et al., 2011). Therefore, it is recommended to create a unified list of concepts and contexts, such as product design, functionality, and structure, to establish standardized frameworks for technology and engineering education curricula (Rossouw et al., 2011).

The findings regarding the second research question revealed the plethora of studies on students' and teachers' personal factors as well as on their interactions and classroom discourse. This review synthesizes studies on both students and teachers to give a comprehensive understanding of the intricate aspects of education and the acquisition of knowledge (Charalambous, 2015; Kilpatrick et al., 2001; Vermunt, 2005). Sixteen articles examined students' personal factors (Table 5), eight articles focused on teachers' personal factors (Table 6) (i.e., personal factors), and nine articles on student–teacher personal and contextual factors (Table 7). In alignment with previous research, several studies argued that teachers' personal and contextual factors are strongly connected to students' personal factors (i.e., knowledge, perceptions, and attitudes) about technology and engineering education (Douglas et al., 2016; Post & van der Molen, 2014; Rohaan et al., 2010; Vermunt, 2005). This leads us to further recognize the importance of TPDs for fostering teachers' technology acceptance and information technology skills (Deniz et al., 2020; Douglas et al., 2016; Koul et al., 2018). TPDs should support teachers to understand, experiment, and reflect on the contexts, procedures, and approaches of technology and engineering education, leading to increased confidence and successful implementation of technology in the classroom (Mangiante & Gabriele-Black, 2020; Stein et al., 2000; Watkins et al., 2021).

This review study seeks to analyze and synthesize relevant research articles about the current status of technology and engineering education, taking into account all key stakeholders in primary education, including teachers, students, and the classroom environment. Therefore, our findings have implications for both research and practice, providing a framework for discussing advancements in technology and engineering education research. Specifically, our findings provide the necessary common ground for understanding the concepts and aims of technology and engineering curriculum. This study also emphasizes the important role technology plays in primary schools and urges future studies to focus on the development and implementation of technology-oriented professional development programs for pre-service and in-service primary school teachers.

In sum, this study serves as a valuable knowledge base and enhances the understanding of technology and engineering education from the perspectives of both teachers and students. Building upon the current findings, our future research endeavors will involve the development of a Teacher Development Program (TDP) focused on technology education in primary schools in Germany. This program aims to bridge the gap between theory and practice in the field by providing professional development opportunities to motivate, prepare, and support teachers in the design and implementation of technology-focused lessons in primary school classrooms. By incorporating practical training and ongoing support, we aim to facilitate the effective integration of technology education into primary school curricula.

Limitations

Our review study has several limitations that need to be acknowledged. Firstly, we focused solely on research articles published in journals, neglecting potentially valuable information from sources such as conference proceedings, which may not be widely accessible or published at an international level due to language barriers. Secondly, our investigation specifically targeted in-service teachers to examine their implementation processes in technology and engineering subjects and their impact on students' personal skills and classroom interactions. However, it would be beneficial to have an overview of pre-service educational programs related to technology and engineering subjects. Understanding teachers' backgrounds in these subjects is crucial for establishing and enhancing the foundational frameworks for the development of effective TPD programs. Recognizing these limitations is important as they provide insights into areas for future research and potential avenues for improving the comprehensiveness and depth of our study.

Conclusion

In conclusion, the growing interest and research in technology and engineering education highlight the need for a shared understanding of its objectives, concepts, and contexts to establish cohesive curricular frameworks and implementation practices. Our study contributes to the field by shedding light on the current state, diversities, and challenges within technology and engineering education in primary schools. This insight can inform further research endeavors and policymaking, ultimately facilitating the development of effective TPD programs in this domain. By addressing the existing gaps and challenges, we can advance the quality and impact of technology and engineering education in primary schools.

Acknowledgements This study was funded by TÜV SÜD Stiftung.

Author contributions All authors contributed to the study conception and design. The literature search was performed by the first author, and the data analysis by the first and second author. The first draft of the manuscript was written by the first author and all authors commented on previous versions of the manuscript. All authors read and approved the final manuscript.

Funding Open Access funding enabled and organized by Projekt DEAL.

Declarations

Conflict of interest The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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