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Evolving Technology Education in Primary Schools: A Two-Decade Journey Through a Systematic Review and Teacher Insights

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To my beloved son, Alexander.

You have made me stronger and more fulfilled than I could have ever imagined.

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Abstract

The significance of technology is steadily increasing as society undergoes rapid advancements. However, in STEM education, technology and engineering receive less emphasis, especially in primary schools where technology education often focuses solely on computer science, neglecting practical aspects. The lack of uniform standards in describing technology education across different educational levels and regions presents challenges in its effective implementation. To address this issue, this dissertation seeks to investigate the status and definition of technology education research, examine teachers' experiences with technology integration, identify challenges, and determine areas that the teachers require support. The aim of this dissertation is to lay the foundation for the technology curriculum, understand teachers' needs, and develop professional development initiatives to enhance technology education.

The research findings from this dissertation are published journal articles based on two different studies. The first study presents a systematic review of technology education in primary schools, examining the terminology used in technology and engineering education. It emphasizes key aspects of teaching and learning that must be considered in the context of technology and engineering education, including personal factors of students and teachers, classroom communication, and teacher professional growth. Following PRISMA guidelines, the review analyzed 1206 papers from electronic databases, leading to the selection of 33 relevant papers. The results highlight the growing interest in technology education in primary schools but also reveal a fragmented research focus. The review uncovers a wide range of definitions for technology and engineering education, indicating a lack of clarity in concepts and aims within curricula.

The second article discusses the advantages of integrating technology in primary school curricula, with a specific focus on teachers' experiences with technology integration. While previous studies have highlighted the benefits of using technology in education, the perspectives of teachers have often been neglected. To address this, the study conducted semi-structured interviews with teachers to explore their current experiences with technology integration, identifying challenges and areas that need support. The analysis determined that content knowledge, proper training, and professional development programs were essential for successful technology

integration. Additionally, the establishment of clear and unanimous curricula standards and teaching communities for collaborative learning were identified as important factors in effectively incorporating technology into primary school education.

Overall, this dissertation contributes with insights to enhance teachers' technology acceptance and teaching practices related to technology and engineering. The findings have significant implications for research and practice, serving as a foundation for well-structured professional development courses tailored to teachers' needs in technology education. The dissertation emphasizes the significance of efficiently integrating technology education in primary schools to improve student learning experiences in the ever-changing technological environment.

Zusammenfassung

Die Bedeutung der Technik nimmt stetig zu, während die Gesellschaft rasante Fortschritte macht. In der MINT-Bildung wird jedoch insbesondere in der Grundschule weniger Wert auf Technik und Ingenieurwissenschaften gelegt. In der Grundschulbildung konzentriert sich die Technologieausbildung oft auf die Informatik und vernachlässigt praktische Aspekte. Das Fehlen einheitlicher Standards zur Beschreibung der technischen Bildung auf verschiedenen Bildungsebenen und in verschiedenen Regionen stellt eine Herausforderung für ihre effektive Umsetzung dar. Um dieses Problem anzugehen, zielt diese Dissertation darauf ab, den Status und Definition der technischen Bildungsforschung zu untersuchen, die Erfahrungen von Lehrkräften mit der Integration von Technik zu erforschen, Herausforderungen zu identifizieren und Bereiche zu bestimmen, die Unterstützung benötigen. Das Ziel dieser Dissertation besteht darin, die Grundlagen für den Technik-Lehrplan zu legen, die Bedürfnisse der Lehrkräfte zu verstehen und Weiterbildungsmaßnahmen zu entwickeln, um die technische Bildung im Grundschulbereich zu verbessern.

Die Forschungsergebnisse aus dieser Dissertation werden in wissenschaftlichen Artikeln veröffentlicht, die auf zwei verschiedenen Studien basieren. Die erste Studie präsentiert eine systematische Überprüfung der technischen Bildung an Grundschulen, in der die in der technischen und ingenieurwissenschaftlichen Bildung verwendete Terminologie untersucht wird. Sie legt besonderen Wert auf Schlüsselaspekte des Unterrichts und des Lernens, die im Kontext der Technik- und Ingenieurausbildung berücksichtigt werden müssen, einschließlich persönlicher Faktoren von Schüler*innen und Lehrkräften, Unterrichtskommunikation und berufliches Wachstum der Lehrkräfte. Gemäß den PRISMA-Richtlinien wurden 1206 Arbeiten aus elektronischen Datenbanken analysiert, was zur Auswahl von 33 relevanten Arbeiten führte. Die Ergebnisse heben das wachsende Interesse an der technischen Bildung in Grundschulen hervor, zeigen jedoch auch einen fragmentierten Forschungsfokus auf. Die Überprüfung zeigt eine Vielzahl von Definitionen für Technik- und Ingenieurausbildung auf, was auf einen Mangel an Klarheit in Bezug auf Konzepte und Ziele in Lehrplänen hinweist.

Der zweite Artikel diskutiert die Vorteile der Integration von Technik in Grundschullehrplänen mit einem speziellen Fokus auf die Erfahrungen der Lehrkräfte mit der Technikintegration. Während frühere Studien die Vorteile der Verwendung von

Technik in der Bildung hervorgehoben haben, wurden die Perspektiven der Lehrkräfte oft vernachlässigt. Um dies zu adressieren, wurden für die Studie halbstrukturierte Interviews mit Lehrkräften durchgeführt, um ihre Erfahrungen mit der Integration von Technik festzustellen, Herausforderungen zu identifizieren und Bereiche zu bestimmen, die Unterstützung benötigen. Die Analyse ergab, dass Fachwissen, angemessene Schulungen und berufliche Weiterbildungsprogramme für eine erfolgreiche Integration von Technik unerlässlich waren. Darüber hinaus wurde die Festlegung klarer und einheitlicher Lehrplanstandards sowie Lehrergruppen für kooperatives Lernen als wichtige Faktoren identifiziert, um Technik effektiv in die Grundschulbildung zu integrieren.

Insgesamt trägt diese Dissertation dazu bei, Einblicke in die Akzeptanz von Technik durch Lehrkräfte und deren Lehrpraktiken im Zusammenhang mit Technik und Ingenieurwissenschaften zu verbessern. Die Ergebnisse haben bedeutende Auswirkungen auf Forschung und Praxis und dienen als Grundlage für gut strukturierte berufliche Weiterbildungsmaßnahmen, die auf die Bedürfnisse der Lehrkräfte in der technischen Bildung zugeschnitten sind. Die Dissertation unterstreicht die Bedeutung einer effizienten Integration von Technik in Grundschulen, um die Lernerfahrungen der Schüler*innen in der sich ständig verändernden Welt zu verbessern.

Inhaltsverzeichnis

1 Introduction and Aim of the Dissertation

In this part of the dissertation, the "Introduction" reveals the research background, explains the context, and the dissertation's relevance. The "Aim of the Study" section clearly outlines the specific goals and objectives, giving a roadmap to understand the dissertation's purpose and expected contributions to the academic field.

1.1 Introduction

Technology's widespread impact is becoming more noticeable in our society, reaching into different areas such as education (Mammes, 2014; Mammes et al., 2019). However, technology's role in general education often lacks the attention it deserves, particularly in comparison to STEM subjects (Science, Technology, Engineering, and Mathematics) like mathematics and science (Bozick et al., 2017; de Vries, 2019). Technology education is often confined to disciplines such as informatics, computer science, and digital tools (Davies, 2011; Firat, 2017; Wender, 2004) along with engineering, creating challenges as their objectives often overlap (Boeve-de Pauw et al., 2020; Rossouw et al., 2011).

In this dissertation, technology is referred as the tangible framework of artifacts and their utility, emphasizing its role as a human-developed tool (Firat, 2017; Ropohl, 1991). The focus here is on technology education, also known as technical education, which includes technological processes, artifact design, and solutions to technological challenges within cultural contexts. This definition excludes e-learning and online tools, focusing instead on integrating technology-related subjects into teaching practices.

Technology education curricula and course descriptions exhibit a notable degree of variation, lacking a unified consensus regarding the objectives and educational goals of technology education (Sherman et al., 2010). Thereby, the integration of technology-related subjects and initiatives for professional development in both pre-service and in-service teacher education programs remains underdeveloped (Blömeke et al., 2010; Bozick et al., 2017; Mammes et al., 2016). To promote positive student attitudes and essential skills in technology education, teachers need a clear understanding of technology and confidence in their teaching abilities (Davies, 2000; De Vries, 2000). Previous research suggested that a limited understanding of technology education could hinder their ability to incorporate technology-related topics into teaching practices (Çengel et al., 2019; Gibson, 2009; Wang et al., 2011). Teachers need a clear understanding of technology to foster positive student attitudes, and both training and technical expertise are crucial for successful lesson planning and implementation (Mammes et al., 2016; Rohaan et al., 2009).

The integration of technology is necessary for preparing students for a technology-driven society and addressing gender stereotypes in STEM subjects (e.g., Jakobs & Ziefle, 2010; Mammes et al., 2016; Wright et al., 2018). During primary school years, children develop perceptions of societal roles, making it essential to counter stereotypes suggesting that girls lack technological aptitude (Blümer, 2019).

To effectively advance the cause of technology education, establish standardized curriculum guidelines, and provide adequate training for both current and future educators, it is essential to initially assess the prevalence of technology education, identify existing issues and perceived obstacles in the incorporation of technological practices, and assess the competence and confidence levels of teachers regarding technology integration.

1.2 Aim of the Dissertation

Recognizing the limited research in this domain, the overarching aim of this dissertation is to provide a comprehensive understanding of technology education in primary schools by synthesizing empirical research from the past two decades and by exploring primary school teachers' perspectives and experiences related to technology education. The first major objective of this dissertation is to critically analyze the existing literature to clarify how technology education in primary schools has been defined over the past two decades. Additionally, it aims to assess the extent to which empirical studies have delved into the personal factors of both teachers and students, as well as the classroom environments that facilitate effective technology education. By addressing these questions, the dissertation seeks to establish a strong foundation for understanding the current state of technology education in primary schools.

The second primary objective of this dissertation is to shed light on primary school teachers' practices, perceptions, and challenges concerning technology-related subjects. By investigating teachers' perspectives on the value of technology education, their competencies in delivering technology-related content, and the support they receive, the dissertation aims to identify areas for improvement and enhancement in teacher training and support. Additionally, it seeks to examine the current integration of technology-related subjects in primary schools and uncover the challenges and barriers faced by teachers in this context. This research endeavors to provide evidence-based solutions that can support both in-service and pre-service teachers in delivering effective technology education, ultimately enhancing the technological skills and engagement of both teachers and students in technology education within the primary school setting.

2 Included Publications

The present dissertation is a publication-based dissertation and consists of two articles published in international peer-reviewed journals. The author of this dissertation is the first author of both articles and played the leading role in the development, conceptualization, development of instruments, data collection, coding, analyses, writing these manuscripts, and revisions. The second author, Dr. Despoina Georgiou, was also the second coder in both studies and provided her support and expertise in the data analysis of both studies. All authors provided critical reviews of the manuscripts and revisions as well as read and approved the submitted versions.

The first journal article was submitted to the journal of International Journal of Technology and Design Education (ISSN: 1573-1804) in February 2022 and accepted in September 2023.

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The second journal article was submitted to the journal of International Journal of Technology and Design Education (ISSN: 1573-1804) in January 2023 and accepted for publication in April 2023.

> Pappa, C. I., Georgiou, D., & Pittich, D. (2023). Technology education in primary schools: addressing teachers' perceptions, perceived barriers, and needs. International Journal of Technology and Design Education. https://doi.org/10.1007/s10798-023-09828-8

3 Theoretical Background

This section delves into the theoretical background that forms the basis of the dissertation's research. The subchapter "3.1 Technology Education and the Challenges of Its Implementation" examines the complexities related to the integration of technology in education, shedding light on the obstacles encountered. The section titled "3.2 Teacher and Student Personal Factors and the Integration of Technology in Primary School" examines how the personal factors of teachers and students affect the use of technology in primary schools. These subchapters provide a thorough exploration of the important theoretical foundations for understanding the research context of the dissertation.

3.1 Technology Education and the Challenges of Its Implementation

The pervasive influence of technology is steadily growing, encompassing all facets of our society, including the realm of education (Mammes, 2014; Mammes et al., 2019). However, technology in general education often receives insufficient attention and emphasis, particularly in comparison to other STEM subjects like mathematics and science (Bozick et al., 2017; de Vries, 2019). Technology is frequently confined to associations with informatics, computer science, and digital tools (Davies, 2011; Firat, 2017; Wender, 2004), and on occasion, engineering. The combination of these subjects presents challenges as their objectives and implementation processes frequently overlap (Boeve-de Pauw et al., 2020; Rossouw et al., 2011).

Variances in the depiction of technology education are prevalent across different educational levels, from primary schools to higher education, both nationally and regionally (Keskin, 2017; Mammes et al., 2016; Rasinen et al., 2009; Williams, 2006) The absence of uniform standards concerning its definition, status, content, objectives, and pedagogical approaches hinders its effective integration (Rasinen et al., 2009; Williams, 2006).

In this dissertation, the definition of technology is adopted from Ropohl (2009) and the German term "Technik," which highlights technology as the tangible and operational framework of artifacts and their utility, emphasizing technology as a human-developed tool for specific purposes (Firat, 2017; Ropohl, 1991). The focus of this dissertation is on technology education, also known as technical education, encompassing the technological processes linked to artifact functionality, design, and solutions for identified technological challenges within social and cultural contexts.

In a previous study conducted by Ropohl (2009), the concept of technology is thoroughly examined across its multifaceted dimensions. Technology can be defined as a composite of distinct elements: (a) the abundance of user-centric, man-made, tangible entities, often referred to as artifacts or technical object systems; (b) the multitude of human actions and facilities involved in the creation of these technical object systems; and (c) the diverse array of human activities in which these technical object systems are employed (Ropohl, 2009, p. 31). In simpler terms, technology encompasses everything that is not naturally occurring but has been deliberately crafted by humans for specific purposes. Ropohl asserts that technology can be observed from three distinct dimensions: the human dimension, the natural dimension, and the social dimension (see Figure 1). According to him, it is essential to recognize that technology cannot be comprehended in isolation from these dimensions.

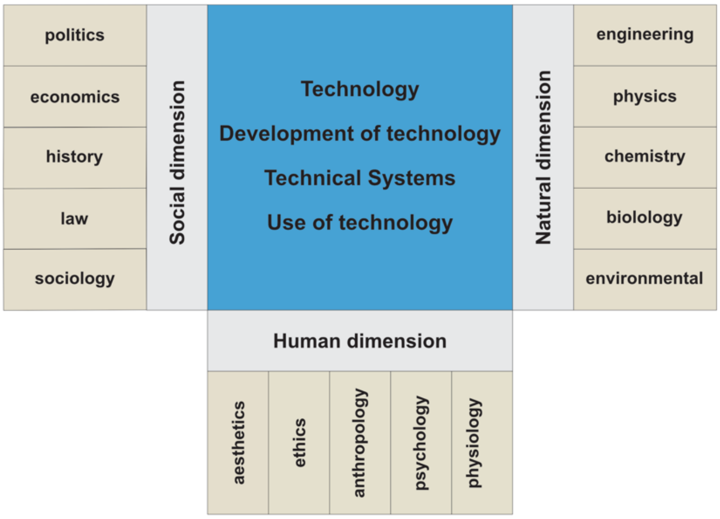

Figure 1: The different dimensions of technology as a school subject (Ropohl, 2009, p. 32)

Binder (2020) underscores the significance of these dimensions through the illustration of a sports shoe. In the human dimension of sports shoe development and utilization, various factors come into play, including individuals' ethical principles, their aesthetic preferences (such as color, shape, and tactile qualities), and the physiological characteristics of the human foot and body (Binder, 2020). From the natural dimension, attention is given to the physical aspects involved, such as the mathematical calculation of the processes and forces occurring during running (Binder, 2020). Lastly, the social dimension encompasses considerations related to fashion trends, societal categorizations, and lifestyle patterns (Binder, 2020). In summary, Ropohl's (2009) definition underscores the importance of embracing diverse viewpoints and influences when discussing technology.

It's crucial to clarify that in this dissertation the concept of technology integration does not pertain to e-learning or online tools but rather encompasses the incorporation of technology-related subjects into teaching practices. For example, this involves exploring the functionalities of everyday electrical appliances like toasters and mixers.

As previous studies have indicated, discrepancies in the objectives and understanding of technology education persist, which is reflected not only among different countries but also within a single country's provinces and districts (Keskin, 2017; Mammes et al., 2016; Rasinen et al., 2009). Some countries, such as New Zealand and Sweden, designate technology education as a standalone subject within the curriculum (Milne, 2013; Sultan et al., 2020), whereas in others, it is merely a subcomponent of science-related subjects like physics (Rasinen et al., 2009).

The absence of standardized frameworks for defining, structuring, and establishing the objectives of technology education in primary schools worsens the challenges associated with integrating and implementing technology in classrooms (Rasinen et al., 2009; Wammes et al., 2022). These disparities are particularly pronounced in various European nations, including Germany, Austria, Estonia, and Finland, where a lack of uniform curriculum frameworks concerning aims, integration, and instructional implementation prevails (Rasinen et al., 2009).

For instance, in Germany, there are no nationwide educational standards, and each state formulates its own curriculum. Consequently, the scope, standards, and time allocated to technology education can vary even within schools in the same state (Koch et al., 2019; Mammes et al., 2016; Mammes et al., 2012). The absence of a cohesive curriculum, coupled with the inadequate attention accorded to technology education, is unsurprising, as technology is often treated as a subsidiary component of the broader "general science" subject, which differs across states (Koch et al., 2019; Mammes et al., 2016). These inconsistencies, alongside the lack of explicitly defined objectives and conflicting implementation procedures, have also engendered disparities in teacher training for technology education (Blömeke et al., 2010; KMK, 2008). For example, in the state of Bavaria, where one study of this dissertation was conducted, technology-related subjects are not mandatory in pre-service teacher education. Instead, they are elective components under the broader "natural sciences and technology" category (Blömeke et al., 2010). Consequently, pre-service teachers' familiarity with technology education depends largely on their elective choices.

These discrepancies in curriculum and the absence of a standardized teacher-training program can potentially undermine teachers' competence and confidence when tasked with integrating technology into their teaching practices (Mammes et al., 2012; Möller et al., 1996; Rohaan et al., 2009). To promote positive student attitudes and cultivate essential skills (e.g., problem-solving, critical thinking, design, and construction skills) in the realm of technology education, it is crucial that teachers have a clear understanding of technology and feel confident in their ability to teach this subject (Davies, 2000; De Vries, 2000).

Just as teachers, students' proficiency in technology and their active engagement with technology and engineering topics can facilitate a stronger connection between their daily experiences and these subjects, leading to the enhancement of their critical thinking and problem-solving capabilities (Sneider & Ravel, 2021; Wright et al., 2018). A positive disposition towards technology among students often correlates with a more comprehensive and precise comprehension of technological aspects (Rohaan et al., 2010). Conversely, students who lack confidence and competence in their technological skills may tend to overlook these subjects in their learning journeys (Rasinen et al., 2009). To be more specific, an inadequacy in technological proficiency can constrain students' choices and decisions regarding their educational paths, including university courses and vocational training (Mammes et al., 2012; Rohaan et al., 2010).

Previous studies have emphasized that using technology is essential for various reasons. If students don't receive enough technology education in their early years, they may lack confidence in dealing with technology (Mammes et al., 2016). This could lead to adults who are not well-prepared to take part in and contribute to a society driven by technology (Jakobs & Ziefle, 2010; Mammes et al., 2016). Integrating technology at the primary school level is crucial in addressing gender stereotypes and motivational disparities in STEM subjects (Mammes et al., 2016; Wright et al., 2018). During this formative stage, children develop perceptions of societal role assignments, requiring proactive steps to prevent the reinforcement of stereotypes that imply girls lack technological aptitude before they enter secondary education (Blümer, 2019).

3.2 Teacher and Student Personal Factors and the Integration of Technology in Primary School

The way in which students acquire knowledge is influenced by the interplay between personal and contextual factors (Vermunt, 2005). Personal factors, such as beliefs, perceptions, competencies, gender, age, etc., provide a consistent framework for learning, while contextual factors introduce variability (Vermunt, 2005). The contextual factors are associated with the learning activities that students engage in. One of the most critical and direct contextual factors is the instructional approach employed, making the teacher's role central to the learning process (Vermunt, 2005). Teachers' personal factors, encompassing their knowledge and perceptions of a teaching discipline, can significantly shape the integration of that subject into their instructional practices and pedagogical approach (Charalambous, 2015; Georgiou, Diery, et al., 2023; Georgiou et al., 2020; Kilpatrick et al., 2001; Vermunt, 2005). Prior studies have demonstrated that teachers who expressed a lack of expertise in a particular teaching subject encountered difficulties when attempting to incorporate a variety of activities into their teaching methods (Çengel et al., 2019; Gibson, 2009; Wang et al., 2011). The current dissertation focused on student and teacher personal factors as well as classroom environments because learning is a complex process and should be examined holistically. Personal factors, such as knowledge and beliefs, are strongly related and both contribute to teaching and learning procedures (Charalambous, 2015; Georgiou, Diery, et al., 2023; Georgiou et al., 2020; Kilpatrick et al., 2001; Vermunt, 2005). Prior research has highlighted the significant interaction between individual factors, including age, beliefs, knowledge, and attitudes, and contextual factors such as the classroom environment, interactions between students and teachers, and instructional methods, in shaping the learning experiences within a classroom environment (Vermunt, 2005).

The research and literature surrounding technology education in primary schools are gaining momentum, often focusing on STEM subjects while overlooking the distinct domain of technology education. This tendency arises primarily from the inconsistencies evident within curricula and the absence of specialized teacher-training programs dedicated to the professional development of primary school teachers in technology education. The integration of technology and STEM is closely linked to teachers' training and their perceptions of their own competencies, capabilities, and readiness to impart technology-related subjects (Margot & Kettler, 2019).

Teachers' perceived competencies can significantly impact their preparedness to engage with and incorporate technology-oriented subjects into their instructional plans (Bell, 2016; Margot & Kettler, 2019). Teachers' perceptions regarding the significance of STEM disciplines play an important role in their professional growth as educators well-versed in STEM subjects (Bell, 2016). These perceptions also hold considerable influence on their tendency to incorporate technology-related subjects into their teaching curriculum (Margot & Kettler, 2019; McMullin & Reeve, 2014).

Teachers believe that the integration of STEM and technology can have a positive impact on their students' development. It enhances students' critical thinking abilities concerning present and future issues and augments their scientific literacy and overall learning outcomes (Gibson, 2009; Margot & Kettler, 2019).

Several studies have documented that teachers often lack confidence in their content knowledge related to STEM subjects and encounter challenges when it comes to integrating and working with technological resources in their educational institutions (Landwehr et al., 2021; Möller, 2010; Rohaan, 2009; Yu et al., 2021). In contrast to other subjects, teachers frequently struggle with a limited understanding of the nature of technology education. This limited comprehension poses challenges when attempting to incorporate technology-related topics into their teaching practices (Çengel et al., 2019; Gibson, 2009; Wang et al., 2011).

Inconsistent educational standards within technology education can influence both students' and teachers' personal factors, encompassing beliefs, perceptions, competencies, and more (Georgiou, Trikoili, & Kester, 2023; Mammes et al., 2012; Möller et al., 1996), as well as teachers' decisions pertaining to lesson planning (Georgiou, Trikoili, & Kester, 2023; Mammes et al., 2016). Proficiency and confidence are prerequisites for teachers involved in technology education (Davies, 2000; Möller et al., 1996).

It is imperative for teachers to acquire a coherent and unambiguous understanding of the concept of technology to promote favorable student attitudes toward the subject

(De Vries, 2000). The absence of training and technical expertise among teachers can impact their lesson planning and implementation, potentially contributing to resistance toward technology education (Mammes et al., 2016; Rohaan, 2009).

4 The Present Research

In this section, the spotlight is on the specific focus of the dissertation, featuring the aims and research questions outlined in Journal Article I and Journal Article II. This chapter provides a clear roadmap to grasp the distinct research goals and questions that frame the subsequent analyses and findings in the dissertation.

The overarching aim of this dissertation is to comprehensively investigate and enhance the landscape of technology education in primary schools by synthesizing empirical research and amplifying the voices of primary school teachers. Firstly, it seeks to provide a holistic understanding of how technology education has been defined over the past two decades and the extent to which empirical studies have focused on the personal factors of teachers and students, as well as the classroom environments that facilitate effective technology education. Secondly, it aims to shed light on primary school teachers' practices, perceptions, and challenges related to technology education. By addressing these aims, this research endeavors to offer evidence-based solutions and implications for technology education in primary schools.

The dissertation's contribution to the research on technology education lies in its ability to inform curriculum development, teacher training programs, and policy initiatives based on the current state of technology education and the factors influencing its implementation. Furthermore, by highlighting teachers' perspectives and challenges, the research can provide valuable insights to create targeted support systems that ensure teachers possess the necessary competencies and resources for delivering effective technology education. Ultimately, the research and findings of this dissertation could enhance technology education for both in-service and pre-service teachers, with the broader implication of promoting technological skills and engagement among primary school students.

4.1 Journal Article I

The primary objective of this literature review study is to analyze how technology education in primary schools has been outlined in empirical studies conducted over the last two decades. In addition to clarifying terminology, the study aims to examine how much empirical research has focused on the personal factors of both teachers and students, as well as the classroom settings that support effective technology education. To accomplish this, a broad spectrum of subjects, methodologies, and research designs is employed to examine the present body of research. Specifically, the literature review addressed the subsequent research inquiries:

1) How is technology education in primary schools defined based on empirical studies from the last two 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?

This review included all aspects of education, such as primary school teachers, students, and classroom environments for several significant reasons. Technology and engineering education at the primary level is often given minimal attention or is briefly touched upon within other subjects, such as science (Mammes et al., 2016; Wright et al., 2018). Technology education holds the potential to enhance the development of personal attributes among both students and teachers (Douglas et al., 2016; Post & van der Molen, 2014; Rohaan et al., 2010). A lack of exposure to technology during the early years of schooling can negatively affect students' competencies, future career choices, and reinforce gender stereotypes (Jakobs & Ziefle, 2010; Mammes et al., 2016).

4.2 Journal Article II

Recognizing the limited research in this domain and with the aim of amplifying the voices of teachers, this study was dedicated to shed light on the practices employed by primary school teachers in implementing technology-related topics. Furthermore, it sought to ascertain the significance they attribute to technology education, while investigating the barriers they perceive and the areas in which they require assistance. The objective was to delve into teachers' requirements and their perspectives on technology education, with the goal of offering evidence-based solutions that can strengthen the technology education of both in-service and pre-service teachers. Consequently, the study addressed the following research questions:

1) What are primary school teachers’ perceptions about the value of, their competencies in, and the support they receive when teaching technology-related subjects?

2) What is the current integration of technology-related subjects in primary schools, and what are the challenges/barriers primary school teachers face when teaching technology-related subjects?

5 Methodology

The present dissertation was part of the research project titled "Teachers' Professional Development in Science and Technology in Primary Schools", funded by TÜV-Süd Stiftung. The project involved the development of a teacher professional program and specific school learning scenarios focused on technical learning in primary schools. The funders were not involved in the study's design, data collection, analysis, the decision to publish, or the preparation of the dissertation and journal articles. The following sections provide a brief overview of samples and methodological details from both journal articles. More detailed descriptions will be given for two specific methodological aspects: a systematic literature review (Journal Article I) and an interview study (Journal Article II).

5.1 Journal Article I

In the section outlining the methods of Journal Article I, the chosen research approach and procedures are presented. Subchapter "5.1.1 Information Sources, Search Strategy, and Inclusion and Exclusion Criteria" illuminates the databases, search strategies, and the inclusion and exclusion criteria used in the literature review. In "5.1.2 Data Collection and Analysis," the methods for gathering and analyzing essential data are described, while "5.1.3 Analysis of Articles" details the procedures for scrutinizing and interpreting the collected articles.

5.1.1 Information Sources, Search Strategy and Inclusion and Exclusion Criteria

A systematic literature review was conducted to gather relevant articles published between 2000 and 2020 from the Web of Science (WoS) Core Collection and Education Resources Information Center (ERIC). The search strategy was carefully developed with the assistance of a librarian, using terms like "technolog* educat*," "primary educat*," "primary school*," "elementary educat*," and "elementary school*." After refining the search string, additional parameters were applied, including a defined time frame, document type (articles, review articles), language (English), and limitation to peer-reviewed articles for increased credibility. The final search in all databases was conducted in January 2023. To identify relevant articles for the research questions, specific inclusion (IC) and exclusion (EC) criteria were established for the selected datasets. The inclusion criteria consisted of the following: IC1: the articles must be published in journals, IC2: they should be written in English, IC3: the studies must be peer-reviewed, and IC4: the articles should not be listed in another database. On the other hand, the exclusion criteria comprised: EC1: studies conducted at educational levels other than primary school, EC2: articles not related to technology, engineering, or technical education, and EC3: studies that do not pertain to primary school students or primary school in-service teachers. These criteria were used to select and include relevant articles for the research.

5.1.2 Data Collection and Analysis

The current systematic literature review followed the PRISMA 2020 guidelines and comprised five phases (see Figure 2) (Page et al., 2021). Initially, a search was conducted in the WoS and ERIC databases, resulting in 282 papers being excluded based on specific inclusion and exclusion criteria. Duplicates were removed, and 74 relevant articles remained. The full texts of these articles were reviewed independently by two authors, resulting in the exclusion of 21 articles that did not meet the predetermined criteria. Additional relevant publications were identified through a manual search, adding 23 papers to the review. Finally, the full texts of the remaining 33 papers were thoroughly examined and evaluated for quality based on the quality evaluation rubric of Mullet et al. (2017). The articles were categorized into three groups for further analysis: Group 1 focused on definitions of technology education stemming from engineering and technology education, Group 2 covered technology education in primary schools for teachers and students, and Group 3 explored classroom practices.

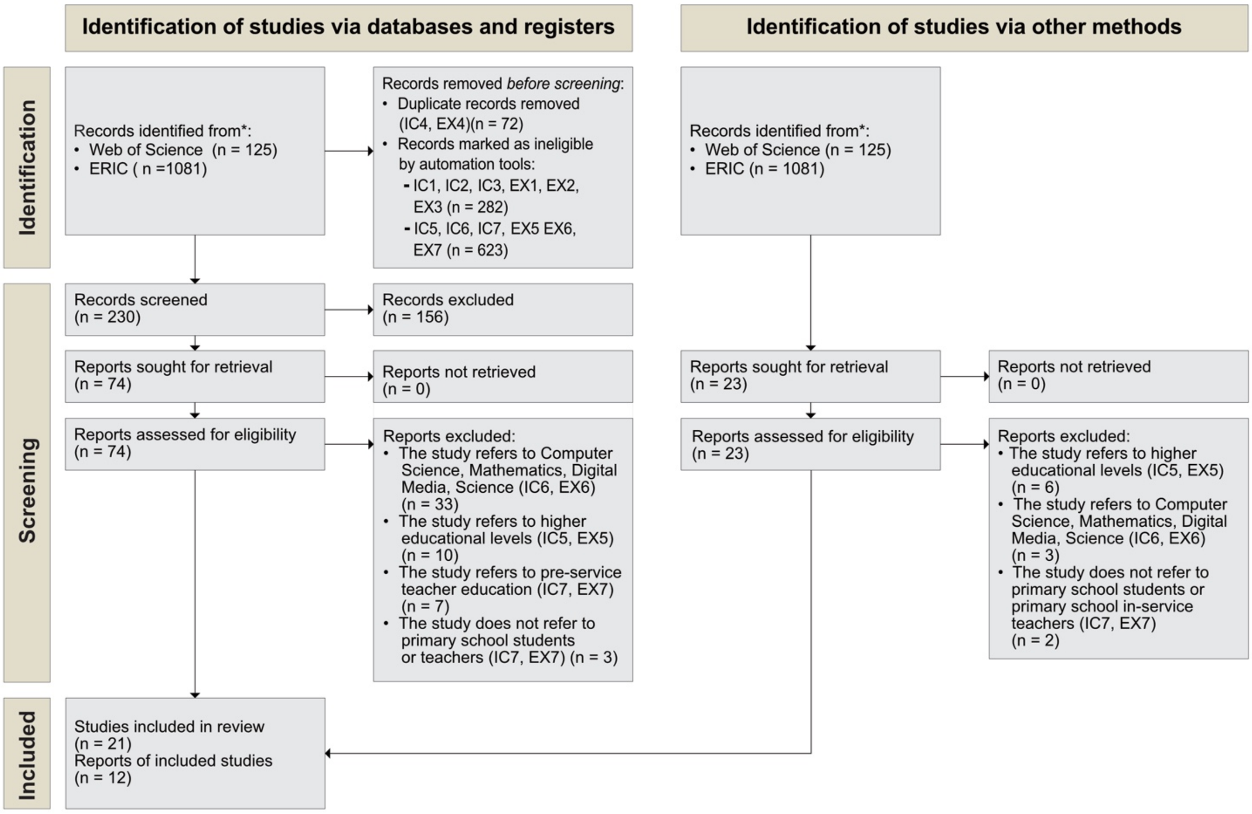

Figure 2: PRISMA 2020 flow diagram (published in Pappa et al., 2023a)

5.1.3 Analysis of Articles

A table was designed to compile and organize information from the selected articles, focusing on specific aspects of each study. The table included details about the study field (i.e., technology and engineering), study population (students, teachers, or classroom environment), sample characteristics, the study's content, research methodology, and primary outcomes. The first author read and analyzed the full text of each article, identifying relevant aspects and completing the table (see Table 1). To ensure accuracy, the second author independently reviewed 30% of the articles, and their results were compared with the first author's.

The content of each study was then categorized into subcategories: a) students' personal factors (beliefs, perceptions, knowledge, skills, attitudes, and group differences), b) teachers' personal factors (beliefs, perceptions, knowledge, skills, attitudes, and teacher professional development), and c) data related to both students and teachers in the classroom learning environment. These subcategories were chosen based on previous research that highlighted the strong relationship between knowledge, beliefs, and their influence on teaching and learning processes

(Charalambous, 2015; Kilpatrick et al., 2001; Vermunt, 2005). Contextual factors, such as the classroom environment and teacher-student interactions, were also found to significantly impact learning experiences in the classroom (Vermunt, 2005).

For each group of studies (Group 1, Group 2, and Group 3), the first author constructed a table containing the content and subcategories. The second author independently analyzed a random 30% of the selected articles to assess agreement, using Cohen's K (Brennan & Silman, 1992; McHugh, 2012). The results revealed excellent agreement between the two raters, confirming the consistency of their analysis.

Table 1: Examples of article summaries (published in Pappa et al., 2023a

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.
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.

5.2 Journal Article II

In the methods section of Journal Article II, the research approach and procedures unfold. Subchapter "5.2.1 Participants and Data Collection" illuminates participant details and data collection methods. "5.2.2 Interviews and Research Design" explores interview design and research methodology, while "5.2.3 Data Analysis" outlines procedures for analyzing collected data.

5.2.1 Participants and Data Collection

The study involved 21 primary school teachers employed in public schools in Bavaria, Germany. The participant group consisted of 19 female and two male teachers ($M_{\text{Years of experience}}$ = 7.50, $SD_{\text{Years of experience}}$ = 5.60). The age distribution indicated that ten participants were below 30 years old, seven were aged between 30 and 40, three were between 41 and 50, and one participant was over 50 years old. To ensure ethical considerations, the privacy and anonymity of participants were safeguarded using codes and pseudonyms. Participants were recruited through their official email addresses and voluntarily took part in the research after providing informed consent. They were contacted via email, invited to participate, and agreed to be part of an online interview study that would be recorded.

5.2.2 Interviews and Research Design

This study employed an exploratory qualitative approach to investigate primary school teachers' perspectives on integrating technology-related subjects, a gap in existing research. It combined deductive and inductive analysis, using initial deductive codes that were modified or expanded based on inductive insights from the data (Brenner, 2006; Korstjens & Moser, 2018; Schreier, 2012). Main codes stemmed from prior research on teachers' STEM perceptions (Margot & Kettler, 2019), while additional codes emerged from participants' responses. This comprehensive strategy enabled a thorough understanding of the research phenomenon, considering established concepts and emerging themes. Semi-structured interviews were chosen to support this approach, offering flexibility to adapt questions based on participant responses, explore unexpected themes, and gather in-depth insights (Kallio et al., 2016). The interviews were conducted face-to-face with German primary school teachers using purposive sampling. They were audio-recorded and verbatim transcribed for meticulous analysis. The interviews were structured into four parts, focusing on technology's importance, teachers' competencies, integration levels, barriers, and perceived support. Researchers refined the interview protocol through expert feedback and think-aloud sessions, ensuring its appropriateness. The interviews, conducted in German in July 2021, ranged from 20 to 30 minutes each.

5.2.3 Data Analysis

Content analysis was employed to examine the interview data (Schreier, 2012), utilizing the MAXQDA Software 2022. The coding framework was developed through a combination of concept- and data-driven strategies (Schreier, 2012), initially based on existing literature and theories about teachers' perceptions of technology integration (Margot & Kettler, 2019), with additional categories added after reviewing all interviews. The verbatim transcription of the interviews was ensured for study credibility (McLellan et al., 2003). To enhance reliability, two independent coders utilized the same coding framework for analysis, and the second coder reviewed and recoded a subset of transcripts (20%) to confirm category presence and coding consistency (Korstjens & Moser, 2018; O'Connor, 2000) (see Table 2). Results demonstrated strong agreement between the two coders (K = .82 [95% CI, .300 to .886], $p < .02$) (McHugh, 2012; O'Connor, 2000).

Table 2: Description of Coding Steps (published in Pappa et al., 2023b)

Coding steps	**Coding steps followed in this study**
Familiarizing with your data	Verbatim transcription. The first author read all interviews several times to understand the data.
Generating initial categories - Concept driven categories	Initial categories were generated based on the literature and the research questions.
Searching for categories in the data - Data driven categories	Further codes were identified after reading all the interviews and general categories were split into subcategories. the categories and subcategories were discussed regarding their relevance to the goals of this study.
Defining and naming the categories	Categories were critically reviewed concerning the coded extracts and the entire dataset.
Intercoder reliability	In the final step, the first author coded all the transcripts, and the second author coded 20% of randomly selected transcripts to verify the presence of the defined categories and ensure the reliability of the coding.

6 Summary of Publications

In the "Summary of Publications" section, the main findings of Journal Articles I and II are presented.

6.1 Journal Article I

The following is a summary of the journal article “Assessing the State of Technology Education in Primary Schools: A Systematic Review of the Last 2 Decades” (see Pappa et al., 2023a). Journal Article I explored the definitions of technology education in primary schools as established by empirical research conducted over the last twenty years. In addition to providing clarity on terminology, this review aimed to delve into the degree to which empirical studies have centered on the personal factors of teachers and students, as well as the classroom contexts that facilitate the effectiveness of technology education.

Regarding the definitions of technology education, 22 of the 33 selected articles revealed a diverse range of definitions and approaches to this field. Technology education was often seen as part of STEM courses, engineering, or science, with varying interpretations across studies. Some emphasized its connection to design and problem-solving (e.g., Boeve-de Pauw et al., 2020; Hong et al., 2011; Milne, 2013), while others highlighted its role in enhancing technological literacy (e.g., Jones & Moreland, 2004; Koul et al., 2018). The distinction between technology and engineering education was also explored, with an emphasis on their interrelatedness in fostering STEM literacy.

Engineering education was defined as a collaborative practice that considers problem spaces, materials, and clients, emphasizing design processes as key components (e.g., Cunningham & Kelly, 2017; Douglas et al., 2016; Mangiante & Gabriele-Black, 2020). These studies also examined the development of design processes in early school years as a critical aspect of engineering education. Overall, the research underscores the importance of design, problem-solving, and the interplay between technology and engineering in technology education and STEM literacy.

The second group of the article analysis delved into the realm of technology education in primary schools. It comprised various facets of student and teacher personal factors in this domain. One critical focus was on students' attitudes toward technology and engineering-based science. Studies by Boeve-de Pauw et al. (2020), Wendell and

Rogers (2013), and Koul et al. (2018) introduced educational interventions that positively influenced students' attitudes. Notably, these interventions were particularly effective in challenging stereotypical beliefs about technology being exclusive to boys, especially among female students. Students' perceptions of technology and engineering were also examined by various studies. Capobianco et al. (2011), Davis et al. (2002), Slangen et al. (2011), and Solomonidou and Tassios (2007) offered insights into how students conceptualize these fields, revealing associations with mechanics, technology's environmental impact, age-dependent understanding, and the impact of problem-solving activities. Studies investigating students' knowledge and skills development highlighted project-based learning as a valuable tool. Gender differences were a recurring theme, with studies like Mammes (2004), Sultan et al. (2020), and Virtanen et al. (2015) shedding light on evolving trends in technological interests, stereotypes, and preferences among male and female students.

Eight articles addressed teachers' personal factors. Notably, Deniz et al. (2020) found that a three-day Teacher Professional Development (TPD) improved teachers' Nature of Engineering (NOE) views, particularly regarding engineering design processes. Watkins et al. (2021) observed changes in teachers' reasoning about teaching engineering design processes after a teacher education program. Stein et al. conducted multiple studies on teachers' beliefs in technology education, emphasizing the influence of prior beliefs and limited knowledge. Rohaan et al. (2012) highlighted the essential role of subject matter knowledge (SMK) in shaping pedagogical content knowledge (PCK) and self-efficacy. Moreland and Jones (2004; 2000) discussed the impact of technology-related knowledge on classroom assessment practices.

The third group of the article analysis investigated teacher-student interactions and the classroom environment in technology education through analysis of nine selected articles. Four studies emphasize the classroom environment within engineering and technology education. Björkholm (2014) underscores the value of group discussions for students' ability to assess suitability for purpose. Cunningham and Kelly (2017) focus on classroom discourse, highlighting communal knowledge development. McFadden and Roehrig (2019) emphasize pedagogical support in engineering design activities, and Fox-Turnbull (2016) identifies distinct conversation stages in technology education.

Several articles explore teacher and student competencies, interactions, and influences. Douglas et al. (2016) examine engineering implementation through Teacher Professional Development (TPD). Mangiante and Gabriele-Black (2020) discuss TPD outcomes on teachers' implementation of engineering design curriculum practices. Lottero-Perdue and Lachapelle (2020) assess students' general and engineering mindsets, noting socioeconomic disparities. Post and van der Molen (2014) investigate technology-oriented company visits' effects on students, with teacher involvement influencing outcomes. Lastly, Rohaan et al.'s (2010) review underscores teachers' Pedagogical Content Knowledge (PCK) in shaping students' attitudes and learning outcomes in technology education.

6.2 Journal Article II

The following section is a summary of the journal article "Technology education in primary schools: addressing teachers' perceptions, perceived barriers, and needs" (see Pappa et al., 2023b). Journal Article II initially addressed the prevailing status of technology integration in primary schools and delved into teachers' perspectives on challenges encountered during the integration process. The investigation also explored primary school teachers' views on the significance of technology, their perceived competencies, and the underlying reasons for the significance of incorporating technology. In the final segment of the results, the study unveiled teachers' identified needs for support when embedding technology into their teaching.

Teachers' perspectives on the value of integrating technology in primary schools revealed multiple dimensions. Five key subcategories emerged from their viewpoints on the value of technology integration: the commonplace use of technology, its future significance, early student exposure, gender-related stereotypes, and the current lack of integration within the curriculum. Nearly all participants (20 out of 21) emphasized technology's importance, with some highlighting its presence in daily life. Several participants foresaw technology's vital role in the future and emphasized its introduction to students at an early stage. Gender-related concerns were also evident, with teachers aiming to break stereotypes and boost girls' confidence in technology. Despite technology being everywhere, there was an agreement that it's not well-integrated into the curriculum, indicating a need for improved frameworks and knowledge in primary education. Overall, the findings underscored the multi-faceted value of technology integration and the challenges associated with effectively implementing it in primary school settings.

In terms of teachers' perceived competencies in incorporating technology-related topics into their lessons, the study identified eight categories explaining their perceived lack of competence: insufficient knowledge, self-doubt, limited exposure to technology subjects during their teacher education, time constraints, complexity of the subject matter, personal school experiences, inadequate teaching experience, and lack of interest. Furthermore, two categories were associated with higher perceived competencies: personal motivation and prior studies. Out of the participants, fifteen indicated feelings of incompetence in technology integration, with fourteen attributing this sentiment to inadequate knowledge. Several participants also pointed to inhibitions about their capabilities (six participants) and the absence of technology-focused education in their training (five participants) as contributing factors. A lack of time and their own school experiences were mentioned by four interviewees as potential influencers on their competence. On the other hand, six female participants expressed relative competence in integrating technology topics, primarily due to personal motivation and genuine interest in the subject matter.

Additionally, the study identified factors impacting primary school teachers' perceived support in technology integration, including materials, personnel, curriculum, and studies. Two types of support emerged: external providers and colleagues/teaching community. Among participants, 15 out of 21 felt unsupported in integrating technology-related topics into lessons, while five reported feeling supported, and one expressed uncertainty about seeking support. Participants noted that available materials and equipment, additional teaching personnel, and incorporation of technology into studies and curriculum could influence their perceived support. External providers, such as professional development programs, were seen as sources of support by 11 teachers, while nine participants looked to colleagues and the teaching community for assistance.

The primary school teachers identified four main reasons for the limited integration of technology in their teaching practices: the pandemic, a broad curriculum, time constraints, and safety concerns related to technology tasks. Seventeen participants indicated that technology integration was relatively low over the past year, with eleven attributing this to the pandemic's impact on distance or virtual education. Additionally, seven teachers cited the broad and undefined curriculum standards as a factor. Safety concerns were noted by two teachers regarding the use of tools, cables, and electricity safety rules. Four teachers, however, reported a relatively high level of technology integration in their classrooms during the same period.

The study also unveiled perceived barriers to technology integration, encompassing 14 subcategories. Prominent barriers included the lack of materials and school equipment, limited knowledge about technology-related topics, safety considerations, time restrictions, and student heterogeneity. Additional impediments involved classroom size, the broad curriculum, teachers' inhibitions, and lack of confidence in technology, teaching room dimensions, and personal interest and educational background. Time constraints and curriculum complexities were underscored, with concerns expressed about imparting accurate knowledge due to teachers' own uncertainties and lack of confidence in certain technology subjects.

7 General Discussion

In this section, a comprehensive exploration unfolds. Section "7.1 Discussion of the Articles" thoroughly examines the findings from both Journal Articles I and II. "7.2 Implications" explores the broader consequences of the research outcomes and "7.3 Limitations and Further Research" addresses the study's constraints and suggests potential avenues for future exploration. Finally, "7.4 Conclusion" provides a summary, highlighting the essential points from the general discussion.

7.1 Discussion of the Articles

The field of technology and engineering education in primary schools has witnessed a notable surge in interest and scholarly attention over the past two decades. This growing interest is supported by a rise in scholarly publications in this field (e.g., Boeve-de Pauw et al., 2020; Davis, 2021; Lavonen, 2021; Lottero-Perdue & Lachapelle, 2020; Sultan et al., 2020; Watkins et al., 2021), indicating an increasing acknowledgment of its importance in the realm of education.

However, as we delve into this domain, it becomes evident that the terminology used in technology and engineering education is far from standardized (Williams, 2006). The definitions and boundaries of these subjects can often overlap, leading to a complex landscape that is not only challenging to navigate but also poses difficulties in establishing successfully uniform standards and curricula (Mammes et al., 2016; Rasinen et al., 2009; Williams, 2006). This lack of consistency is not confined to international disparities; it extends even within the same educational system, creating obstacles to the successful implementation of technology education in primary schools (Georgiou, Trikoili, & Kester, 2023; Mammes et al., 2016; Pappa et al., 2023b).

Crucially, within this complex educational framework, the personal factors of both teachers and students play a pivotal role. Teachers' personal and contextual factors are intrinsically connected to the attitudes and perceptions of their students regarding technology and engineering education (Gibson, 2009; Margot & Kettler, 2019). Consequently, the professional development of teachers emerges as a key factor in fostering technology acceptance and proficiency, ultimately translating into effective classroom practices (Georgiou, Trikoili, & Kester, 2023; Mammes et al., 2016; Pappa et al., 2023b). The perspectives of primary school teachers themselves provide valuable insights into the importance of integrating technology-related subjects into their pedagogy. They underscore the significance of technology integration, not only in terms of its relevance to students' daily lives and future prospects but also as a powerful tool for challenging prevailing gender stereotypes and enhancing motivation, particularly in STEM fields (Blümer, 2019; Mammes et al., 2016; Wright et al., 2018).

Despite this recognition, significant barriers hinder the seamless integration of technology in primary school education. These challenges include the absence of standardized curriculum frameworks, limitations on the time allocated to technology-related topics, and deficiencies in pre-service teacher training (Pappa et al., 2023b). Such obstacles contribute to teachers' perceptions of their own inadequacy and lack of confidence in effectively incorporating technology into their teaching (Mammes et al., 2012; Möller et al., 1996; Rohaan, 2009; Thibaut et al., 2019; Yoon et al., 2018).

Addressing these challenges necessitates a comprehensive approach that extends support and training to primary school teachers (Margot & Kettler, 2019). Their demands for materials, resources, and training are indicative of a profound need for change. This change encompasses curriculum revisions, the inclusion of technology-related content in teacher training programs, collaboration among educators, and the establishment of vibrant teaching communities (Margot & Kettler, 2019; Pappa et al., 2023b). Adequate support and training are pivotal in overcoming the multifaceted challenges associated with technology integration (Pappa et al., 2023b).

Moreover, it is important to recognize additional barriers, including resource limitations, gaps in content knowledge, time constraints, and student diversity. These obstacles, along with concerns about safety, classroom dimensions, curriculum scope, and personal apprehensions surrounding technology, collectively compound the complexity of integrating technology into primary school education (Pappa et al., 2023b).

In conclusion, the landscape of technology and engineering education in primary schools is marked by both promise and complexity. While there is a clear and growing recognition of its importance, addressing the intricate issues of terminology, curriculum consistency, teacher competence, and resource availability is essential to harness its full potential (Pappa et al., 2023a). By providing comprehensive support, training, and clear curricular frameworks, we can navigate these challenges and ensure that technology education in primary schools effectively prepares students for the technological era (Pappa et al., 2023b).

7.2 Implications

The implications drawn from this dissertation encompass various critical parameters for advancing technology education in primary schools. These implications provide valuable guidance for both research and practical application, ultimately aiming to enhance the effectiveness of the integration of technology.

Firstly, the dissertation emphasizes the importance of recognizing the diverse stakeholders involved in primary education, including teachers, students, and the classroom environment. This holistic perspective is essential for understanding the multifaceted landscape of technology and engineering education.

One of the primary implications revolves around the need for establishing a common ground and clear definitions of concepts and goals within the technology and engineering curriculum (Pappa et al., 2023a). The absence of standardized terminology and curriculum frameworks poses a significant challenge. Hence, future research and practice should focus on creating a shared understanding of these subjects to facilitate effective implementation.

The two studies presented in this dissertation underscore the pivotal role of technology in primary schools. They advocate for the development and implementation of technology-oriented professional development programs for both pre-service and in-service primary school teachers (Pappa et al., 2023a, 2023b). Such programs are crucial for bridging the gap between theory and practice, equipping teachers with the knowledge and confidence to design and deliver technology-focused lessons effectively.

The practical implications extend to several key areas. To foster technology integration, efforts should prioritize enhancing teachers' technology content knowledge through practical workshops and hands-on activities (Mammes et al., 2016; Pappa et al., 2023a, 2023b; Rohaan, 2009; Rohaan et al., 2012). These initiatives can boost teachers' confidence and alleviate safety concerns when working with technology in the classroom (Mammes et al., 2016; Pappa et al., 2023b). Furthermore, there is a pressing need for technology-oriented curriculum standards and clear teaching time allocations. Addressing these aspects can simplify the efforts of teachers to integrate technology into their teaching practices. School and state representatives must actively engage in this process, acknowledging the necessity for school equipment and materials to support teachers effectively.

To facilitate collaboration and mutual support among teachers, school principals could consider organizing school intern trainings and technology-related activities. Additionally, dedicated spaces equipped with the necessary materials for technology activities could be established within schools to promote and facilitate technology integration.

In conclusion, the implications drawn from this dissertation underscore the importance of a coordinated and comprehensive approach to technology education in primary schools. By addressing terminology, curriculum clarity, teacher competence, and resource availability, the field can move closer to realizing its potential in preparing students for the technological age.

7.3 Limitations and Further Research

Several constraints need to be considered when interpreting the results of the dissertations. These limitations provide valuable insights into areas that may be subject to improvement and highlight potential avenues for future research. Firstly, in the first journal article presented in this dissertation, it is essential to recognize the study's limitations, notably its exclusive focus on peer-reviewed research articles published in journals. This narrow scope may have restricted the inclusion of valuable information from sources such as conference proceedings, potentially offering unique perspectives and insights, particularly considering the global nature of technology and engineering education.

Additionally, the first journal article's investigation primarily centered on in-service teachers, specifically examining their implementation processes in technology and engineering subjects and their impact on students' personal skills and classroom interactions. However, the absence of an exploration into pre-service educational programs related to these subjects represents a significant limitation. Understanding teachers' backgrounds in technology and engineering is crucial for establishing robust foundational frameworks for the development of effective teacher professional development programs.

Similarly, in the second journal article, limitations arise from its specific focus on primary school teachers' perceptions and experiences with technology use in Bavarian schools. This geographic restriction raises concerns regarding the generalizability of the findings, given potential variations in curricula across different German states. While the qualitative nature of the study aligns with the goal of providing a rich and context-specific understanding of teachers' perceptions and experiences, it is vital to acknowledge that the findings may not be universally applicable to all regions within Germany.

To address this limitation, the second journal article employed a constructivist approach, valuing individual perspectives and experiences in shaping these perceptions. Nevertheless, to alleviate this constraint, the study thoughtfully selected a diverse group of primary school teachers and utilized rigorous data analysis methods to ensure the trustworthiness of the results. However, it is important to acknowledge that the exploratory nature of the study implies the potential for variations among different samples of primary school teachers from various regions.

In summary, these limitations should be considered within the broader context of the dissertation. They underscore the need for future research efforts to explore alternative data sources beyond journal articles and to encompass a more diverse and representative sample of educators. Addressing these limitations is vital for enhancing both the applicability and depth of findings in the realm of technology and engineering education.

Future steps and further studies stemming from the research presented in this dissertation entail the introduction of a professional development program that we have devised to enhance the integration of technology within German primary schools. Our forthcoming research endeavors and the professional development program seek to bridge the gap between theoretical understanding and practical implementation in this field. This is achieved by providing concrete curriculum objectives along with hands-on activities, implementation strategies, and lesson plans. We have leveraged the foundational knowledge provided by these studies to inspire, equip, and support teachers in developing and incorporating technology-driven lessons in primary school settings. Additionally, explored students' motivation and competence levels regarding the integration of technology activities, and the outcomes of these investigations will be presented in upcoming studies.

7.4 Conclusion

In summary, the dissertation reflects the collective findings of two comprehensive studies in the realm of technology and engineering education. These studies underscore the need for a shared understanding of the objectives, concepts, and contextual details within this field to establish cohesive curricular frameworks and effective implementation practices in primary schools.

The insights gathered from these studies illuminate the current landscape, diversities, and challenges inherent in technology and engineering education at the primary school level. This knowledge serves as a valuable foundation upon which future research endeavors and policymaking can be built. By addressing the existing gaps and challenges identified, we can work towards enhancing the quality and impact of technology and engineering education in primary schools.

The studies have delved into primary school teachers' practices, perceptions, and the critical factors influencing the integration of technology. These factors encompass teachers' technology content knowledge, their confidence levels, the imperative need for training, and the necessity for clarity in curriculum standards. These findings offer essential building blocks for future endeavors aimed at standardizing curriculum frameworks and developing and implementing technology-focused professional development programs for both pre-service and in-service primary school teachers.

In conclusion, the combined insights from these studies lay a robust foundation for advancing technology and engineering education in primary schools. They inform the development of strategies to bridge the gap between theory and practice, foster teacher competence, and ultimately enhance the educational experiences of students in the technological age.

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9 Appendix

9.1 Appendix A

Journal Article I:

Pappa, C. I., Georgiou, D., & Pittich, D. (2023). Assessing the State of Technology Education in Primary Schools: A Systematic Review of the Last 2 Decades. International Journal of Technology and Design Education. https://doi.org/10.1007/s10798-023-09851-9

9.2 Appendix B

Journal Article II:

Pappa, C. I., Georgiou, D., & Pittich, D. (2023). Technology education in primary schools: addressing teachers' perceptions, perceived barriers, and needs. International Journal of Technology and Design Education. https://doi.org/10.1007/s10798-023-09828-8