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Technology education in primary schools: addressing teachers' perceptions, perceived barriers, and needs

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Abstract
In primary schools, the benefits of incorporating technology in curricula have been addressed by several studies; however, technology integration as experienced by teachers is often overlooked. Teachers' lack of confidence teaching STEM and technology subjects, their lack of appropriate preparation along with unclear curricula frameworks in technology education, and the ambiguity of the definition of technology education have scarcely been discussed in the literature. This study explored teachers' experiences with the current integration of technology and identified challenges to the integration of technology and areas where support is needed. Semi-structured interviews were used to collect data and were analyzed using content analysis. Content knowledge, proper training, and professional development programs on the integration of technology along with the need for clear and unanimous curricula standards have been perceived as important factors in the integration of technology education. Participants also acknowledged the need for the establishment of teaching communities wherein they can learn from one another. Our study discusses implications for research and practice and provides a knowledge base for the establishment of well-structured professional development courses based on teacher needs.

Keywords Technology education · Primary school teachers · Teachers' perceptions · Technology integration · STEM · STEM integration · Technology integration barriers · Technical education

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Introduction

Although the impact of technology in all areas of society continues to increase, the subject of technology in general education is often not given sufficient attention or emphasis compared to other STEM subjects (i.e., science, technology, engineering, and mathematics), such as mathematics and science (Bozick et al., 2017; de Vries, 2019; Mammes et al., 2019). In the public mind, technology is often only related to computer science and aspects of the integration of technology into e-learning environments or the usage of online tools (Davies, 2011; Firat, 2017; Wender, 2004). In this study, we adopt the definition from Ropohl (2009) and the German word *Technik* (technical), which refers to technology as a tool developed by humans for a purpose or use, and more specifically to technology education as working and understanding about the function and design processes of artifacts (Firat, 2017; Ropohl, 1991). Defining technology and understanding the inconsistencies in definitions of technology are not without controversy in the literature (Rossouw et al., 2011). Several studies have discussed and emphasized the challenge in developing clearly stated curricula standards, along with appropriate teacher training and professional development programs (TPDs) to enhance the integration of technology in education (Blömeke et al., 2010; Keskin, 2017; Mammes et al., 2016; Rasinen et al., 2009). The discrepancies observed among curricula, teacher training, and TPDs may also influence teachers' technology content knowledge and confidence in integrating technology-related subjects into their teaching practices (Mammes et al., 2012; Rohaan, 2009).

It is evident that STEM integration is highly related to teachers' perceived competence, as well as their valuation of and readiness to teach STEM subjects (Margot & Kettler, 2019). Teachers who do not feel confident about their STEM content knowledge or are uncertain about the implementation processes necessary to successfully teach STEM courses may find it difficult to integrate STEM and technology-related topics into their classrooms (Margot & Kettler, 2019; McMullin & Reeve, 2014). The integration of technology-related topics in the classroom is often considered more complicated compared to science and mathematics because teachers are uncertain about the nature and aims of technology education (Çengel et al., 2019; Gibson, 2009; Suwarma & Kumano, 2019; Wang et al., 2011). To successfully promote technology education, establish common curriculum standards, and qualify and support in-service and pre-service teacher professional development efforts, it is first essential to investigate the current status quo of the integration of technology, explore teachers' readiness to teach technology, and identify the challenges of and needs for supporting the integration of technology. In detail, our study explores primary school teachers' technology-related integration practices, sheds light on the value of technology education as perceived by primary school teachers, and identifies perceived challenges and needs for support to establish evidence-based solutions to promote and enhance in-service and pre-service teachers' technology education and teaching practices.

Theoretical background

Technology education

The influence of technology is steadily increasing and has become relevant in all areas of our society, including education (Mammes, 2014; Mammes et al., 2019). However, the

subject of technology in general education is often not given sufficient attention or emphasis, especially compared to other STEM subjects such as mathematics and science (Bozick et al., 2017; de Vries, 2019). Technology is frequently related only to informatics, computer science, digital tools (Davies, 2011; Firat, 2017; Wender, 2004), and sometimes engineering because the aims and the implementation processes of these subjects cannot be easily distinguished from one another (Boeve-de Pauw et al., 2020; Rossouw et al., 2011).

As past studies have revealed, the integration of technology is essential for the following reasons. A lack of adequate technology education in childhood may result in students' lack of self-confidence when dealing with technology, which in turn may create adults who are not capable of functioning and contributing to the development of a technology-driven society (Jakobs & Ziefle, 2010; Mammes et al., 2016). Additionally, the integration of technology during primary school level is considered the most effective time to counteract gender roles and motivational differences in STEM subjects (Mammes et al., 2016; Wright et al., 2018). At this age, children's understanding of social role assignments arise, and therefore, actions should be taken to avoid solidifying stereotypical beliefs that girls are not technologically capable before they enter the secondary schooling (Blümer, 2019).

This study adopts the definition of technology used by one of the most fundamental research of Ropohl (2009) and the German word *Technik*, which is defined as the material and the operational framework of artifacts and their usage, emphasizing the role of technology as a tool developed by humans for a purpose or use. In this study, technology education, also called technical education, is defined as the technological processes related to the function and design processes of artifacts, as well as the solutions for identified technological problems in social and cultural contexts (Firat, 2017; Ropohl, 1991). Thereby, the integration of technology does not refer to e-learning or online tools but to the integration of technology-related topics in teaching practice, such as the function of everyday electrical appliances, for example a toaster, or a mixer.

As past studies have stated, there is a discrepancy between the aims and understanding of technology education that can also be reflected in curriculum, not only among different countries but also between different provinces within one country (Keskin, 2017; Mammes et al., 2016; Rasinen et al., 2009). In a few countries, such as New Zealand and Sweden, technology education has its own place in the curriculum as a primary subject (Milne, 2013; Sultan et al., 2020), but in other countries, technology education is only briefly mentioned as a subtopic of a science-related subject, such as physics (Rasinen et al., 2009). The absence of standardized frameworks for defining, structuring, and establishing the goals of technology education in primary schools contributes to the difficulties faced in integrating and implementing technology in the classroom (Rasinen et al., 2009; Wammes et al., 2022). Such discrepancies are particularly pertinent in several European countries, such as Germany, Austria, Estonia, and Finland, where we observed a lack of unified curriculum frameworks related to the aims, integration, and implementation in instruction of technology education (Rasinen et al., 2009).

For instance, in Germany, there are no statewide educational standards, and each state has its own curriculum—meaning that the scope, standards, and time devoted to technology education may differ even among the schools within the same state (Koch et al., 2019; Mammes et al., 2012, 2016). The lack of a unified curriculum along with the lack of attention given to technology education can be easily understood, as technology is often included as a subtopic of the subject "general science," which differs in each state (Koch et al., 2019; Mammes et al., 2016). The lack of clearly defined objectives and inconsistent implementation processes, along with discrepancies in the curriculum across different states in Germany, has also led to inconsistencies in teacher-training efforts related to the

subject of technology (Blömeke et al., 2010; KMK, 2008). For example, in the state of Bavaria, where the current study was conducted, technology-related topics are not compulsory in pre-service teachers' education—instead, they are elective and included under the broader subject of "natural sciences and technology" (Blömeke et al., 2010). Thus, pre-service teachers' content knowledge about technology education depends mainly on their subject selection.

The inconsistencies among the curriculum and the lack of a unified teacher-training program may have a negative impact on teachers' competence and confidence when they are asked to integrate technology into their teaching practice (Mammes et al., 2012; Möller et al., 1996; Rohaan, 2009). To promote students' positive attitudes and enhance their personal skills (e.g., problem-solving, critical thinking, design and construction skills) toward technology education, it is essential for teachers to have a clear understanding of technology and to feel confident in their own abilities to teach the subject (Davies, 2000; De Vries, 2000).

Teachers' perceptions of the integration of technology education

Research and literature on technology education in primary schools is a growing field of interest, which is often viewed only in the context of STEM and not technology education. This is mainly because of the inconsistencies observed among the curriculum and the lack of teacher-training programs targeting primary school teachers' technology-oriented professional development. Technology and STEM integration is significantly related to teachers' training, along with teachers' perceptions of their competences, abilities, and readiness to teach technology subjects (Margot & Kettler, 2019). Teachers' perceived competences could influence their readiness to engage with and integrate technology-oriented subjects in their teaching curriculum (Bell, 2016; Margot & Kettler, 2019). Teachers' perceptions of the importance of STEM play a significant role in their own professional development as STEM-educated teachers (Bell, 2016) and largely affects their intention to implement technology-related subjects into their curriculum (Margot & Kettler, 2019; McMullin & Reeve, 2014). Additionally, teachers perceived that STEM and technology integration could influence and support their students' development, enhancing students' critical thinking processes about current and future issues, as well as their scientific literacy and learning outcomes (Gibson, 2009; Margot & Kettler, 2019).

Several studies have reported that teachers do not feel confident about their content knowledge related to STEM subjects and face challenges when they need to implement and work with technological equipment in their schools (Landwehr et al., 2021; Möller, 2010; Rohaan, 2009; Yu et al., 2021). This finding was also evident in a recent study from Suwarma and Kumano (2019), where teachers perceived the integration of science and mathematics as less challenging and complicated than the integration of engineering and technology. In comparison to other subjects, teachers often do not clearly understand the nature of technology education, and it is, therefore, challenging to integrate technology related-topics into their teaching practices (Çengel et al., 2019; Gibson, 2009; Wang et al., 2011).

The review by Margot and Kettler (2019) classified potential barriers in STEM integration according to six categories—namely, pedagogical barriers, curricular challenges, structural challenges, student concerns, assessment concerns, and teacher supports. To overcome the pedagogical challenges, teachers need to support a shift to

student-led instruction environments, which can be demanding given the heterogeneity in students' cognitive abilities observed in most classrooms (Margot & Kettler, 2019; Park et al., 2017). Curricular and structural challenges refer to the inflexibility of students' schedules and curricular plans, along with the lack of financial support and technology resources in schools (Margot & Kettler, 2019). Several studies have reported that the broad and undefined curriculum standards are often perceived by teachers as some of the main challenges in integrating technology subjects in their classrooms (Chikasanda et al., 2011; Yu et al., 2021).

Teachers' concerns about assessment refer to the lack of quality assessment processes, planning time, and content knowledge about STEM-related topics (Hammack & Ivey, 2019; Margot & Kettler, 2019). The study by Hammack and Ivey (2019) reported that teachers perceived that their lack of pre-and in-service training affected their background knowledge in technology; additionally, teaching processes were identified as the most important challenges that must be addressed in facilitating engineering and technology education. To support teachers' efforts to develop and enhance their content knowledge in technology research, the implementation of structured and clear curriculum frameworks with specific problem-based tasks that can be easily implemented in classrooms has been recommended (Mammes et al., 2012; Rohaan, 2009). In addition, professional trainings and opportunities for further learning to enhance teachers' competencies in technology may significantly affect teachers' confidence in STEM and technology integration (Mammes et al., 2012; Margot & Kettler, 2019; Rohaan, 2009). Teachers' professional development efforts may prove especially valuable in improving teachers' motivation and confidence in teaching and integrating engineering and technology activities into their classroom instruction (Thibaut et al., 2019; Yoon et al., 2018).

Present study

The importance of the development of both teachers' and students' technological skills and engagement in technology education has already been discussed in teacher-education research (e.g., Boeve-de Pauw et al., 2020; Rossouw et al., 2011; Sherman et al., 2010; Wright et al., 2018). However, technology-related topics and professional development efforts are not yet being properly introduced in pre- and in-service teacher education (Blömeke et al., 2010; Bozick et al., 2017; Mammes et al., 2016). To successfully promote technology education, establish curriculum standards, and properly train in- and pre-service teachers, it is important to first identify the extent to which technology education is taught, the current problems and perceived barriers in the integration of technology practices, and how competent and confident teachers feel regarding the integration of technology.

Acknowledging the lack of research in this field and aiming to hear teachers' voices, this study aimed to shed light on primary school teachers' technology-related implementation practices and valuation of technology education, as well as perceived challenges and areas where support is needed. We sought to explore teachers' needs and perceptions of technology education to provide evidence-based solutions that support the technology education of in- and pre-service teachers and, in the long term, enhance teachers' and students' technological skills and engagement in technology education. Hence, the following research questions are addressed:

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?

Methods

Research design

This study utilized an exploratory qualitative methodology to investigate primary school teachers' perspectives on the integration of technology-related subjects, an area that had not been fully explored in previous research. A combination of deductive and inductive analysis was implemented, with deductive codes used as a starting point and then modified, expanded, or refined based on the inductive insights gained from the data. The main codes were generated based on previous research on teachers' perceptions of STEM subjects (Margot & Kettler, 2019), and additional codes were generated based on the data and participants' answers. This holistic approach allowed for the analysis of the data considering both established concepts and emerging themes to gain a comprehensive understanding of the research phenomenon, capturing both known and unknown aspects (Brenner, 2006; Korstjens & Moser, 2018; Schreier, 2012).

Semi-structured interviews were conducted to support the research approach, as they provided a balanced and flexible way to adapt interview questions based on participants' responses, delve deeper into specific areas of interest, and explore new emerging themes or ideas that may not have been anticipated in advance (Brenner, 2006; Schreier, 2012). The interviews were conducted face-to-face with teachers from different primary schools in Germany, who were selected through purposive sampling. The interviews were audio-recorded and transcribed verbatim, allowing for a thorough and accurate analysis of the data.

Participants

The participants for this study were 21 public primary school teachers working in the state of Bavaria, Germany. The sample consisted of 19 female and two male teachers (see Table 1). The participants' average teaching experience was 7.5 years ($M_{Years\ of\ experience} = 7.50$, $SD_{Years\ of\ experience} = 5.60$). Ten participants were under 30 years old, seven participants were between 30 and 40 years old, three participants were between the ages of 41 and 50 years, and one participant was above 50 years old. In keeping with ethical guidelines, we used codes and pseudonyms to protect the privacy and anonymity of the participants. All participants were recruited via their public email addresses and participated voluntarily in the study. Additionally, they received an invitation email and provided their consent to participate and be recorded in an online interview study.

Table 1 Participants' Characteristics

Name	Gender	Age	Years of experience
Anna	F	30–40 years	7
Emma	F	Under 30 years	3
Eva	F	30–40 years	7
Lucy	F	30–40 years	16
Maria	F	41–50 years	18
Olivia	F	Above 50 years	10
Sara	F	41–50 years	21
Sophia	F	41–50 years	13
Diana	F	Under 30 years	3
Elisa	F	Under 30 years	2
Kate	F	Under 30 years	3
Laura	F	Under 30 years	3
Lena	F	30–40 years	6
Lisa	F	30–40 years	7
Nina	F	Under 30 years	2
Paula	F	Under 30 years	5
Stela	F	30–40 years	5
Natalie	F	Under 30 years	4
Petra	F	30–40 years	17
Daniel	M	Under 30 years	3
Paul	M	Under 30 years	2

Pseudonyms were used to avoid disclosure

Interviews

The semi-structured interviews consisted of four parts (Kallio et al., 2016). In the first part, participants were asked about their perceptions regarding the importance of technology integration in their lessons (e.g., "How important is it for you to integrate technology-related topics into your teaching?"). The second part focused on their perceived competencies in integrating technology topics in their lessons (e.g., "How competent do you feel in your ability to integrate technology-related topics into your teaching?"). The third part focused on their current level of integration of technology topics (e.g., "To what extent have you integrated technology-related topics into your teaching in the past year?") and their perceived barriers to technology integration (e.g., "Which barriers do you think exist in terms of technology integration?"). Finally, participants were asked about their perceptions regarding the support they receive and aspects that could influence perceived support for technology integration (e.g., "To what extent do you feel supported when it comes to technology integration?").

The semi-structured interviews followed a formal interview protocol, but the four interviewers were able to ask follow-up questions when needed to obtain further details from the participants. Expert feedback was obtained from seven researchers in the field of technology education on the initial interview protocol; after the interview protocol was adapted, two think-aloud sessions with primary school teachers were conducted

with two primary school teachers in order to refine the questions. The interviews were conducted in German in July 2021 and lasted from 20 to 30 min each.

Data analysis

Content analysis was used to examine the interviews (Schreier, 2012). The analysis was conducted using the MAXQDA Software 2022. Concept- and data-driven strategies were used to create the coding frame (Schreier, 2012). Based on the literature and existing theories (Margot & Kettler, 2019) about the perceptions of teachers regarding technology integration, the coders defined the main categories. After reading and evaluating all interviews, additional categories were included in the main coding frame (see Table 2).

The interviews were transcribed verbatim (McLellan et al., 2003). To ensure the credibility of the study, two coders used the same coding frame to analyze the interviews, independently of each other (Korstjens & Moser, 2018). To verify the presence of categories and ensure the trustworthiness of the coding, the second coder reviewed and recoded 20% of the transcripts (O'Connor & Joffe, 2020). The results revealed that there was excellent agreement between the two raters ($K = 0.82$ [95% CI, 0.300 to 0.886], $p < 0.02$) (McHugh, 2012; O'Connor & Joffe, 2020).

Results

The results are presented according to the research questions. First, we describe the current integration of technology education in primary schools, along with teachers' perceptions about the challenges faced when integrating technology into their teaching practice. We also explore primary school teachers' perceptions of the value of technology, their perceived competencies, and the potential reasoning attached to the importance of technology integration. In the last

Table 2 Description of Coding Steps

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

results section, we present the teachers' needs for support in the integration of technology into their lessons.

Primary School Teachers' Perceptions Regarding Values, Competencies, and Support Received in the Integration of Technology

Value of integrating technology

Several aspects were addressed by the teachers regarding the value of the integration of technology in primary schools. After carefully reading the interview transcripts, five subcategories were identified: the everyday usage of technology, the need for technology in the future, students' early contact with technology, existing gender stereotypes regarding technology, and the lack of technology in curriculum.

Nearly all interviewees (20 out of 21) discussed the importance of the integration of technology in primary schools. Seven primary school teachers expressed that the integration of technology is essential because of its everyday usage and presence in our lives. Diana said: "I think it's becoming more and more important for children, because technology plays a major role everywhere in our everyday lives and it's a shame if you use it all the time with different appliances, but I don't really know what's behind it and how it all works."

Five interviewees discussed the value of the integration of technology and its importance in the future. Daniel mentioned: "Because I think that's the future, our whole life will be based even more on technology, and if the children don't learn that early on, I'd be afraid that they'll just lose the connection a little bit." The aspect of early contact with the topic of technology was also addressed by three other participants. For example, Eva said: "I think that the earlier the students are confronted with such technical aspects and processes, the sooner this inhibition towards the subject decreases…if they are confronted with it and come into contact with it at an early stage." Three other interviewees added comments regarding the future need for technology and aspects of existing gender stereotypes. Natalie noted:

> Because I simply believe that we will need people later on who work and research in these areas and are interested in them. And I think at least I see it as my job to open this window for the children and to make it appealing to them and perhaps also to take away the fear of such technical topics, where many also hesitate. Or, as they say, it's always a girl–boy issue…these gender-specific narratives…that is always so stereotypically…as a teacher I think is important to somehow break that up, so that the girls simply have the confidence that they can also be good in technology topics….

Additionally, three teachers highlighted the presence of technology both in our current and future everyday lives in contrast to the lack of the integration of technology in the primary school curriculum. Nina expressed the following: "Because our world is becoming more and more technology based, I think it's hard to ignore technology now and although it's so essential in everyday life, there is still lack of frameworks, knowledge, and integration in schools and in the education system…."

Teachers' perceived competencies in integrating technology into their teaching practice

Regarding teachers' perceived competencies in integrating technology-related topics into their lessons, the following eight categories were identified regarding the reasons for their lack of perceived competence: lack of knowledge, inhibitions about their competencies, lack of studying technology subjects during their teacher education, lack of time, complexity of the topic, their own school time experience, lack of teaching experience, and lack of interest (see Fig. 1). Additionally, two further categories were identified as reasons for the teachers' higher perceived competencies: their own motivation and their previous studies.

Fifteen interviewees expressed that they did not feel competent integrating technology topics, and 14 said they felt this way due to a lack of knowledge regarding the subject. For example, Diana said: "Because I have the feeling that I have a rather superficial knowledge of most technological things, and when it really goes into depth, even to explain why or how an appliance is designed or function in detail, I lack the knowledge." Two other aspects that were often mentioned by the participants were their inhibitions about their competencies (six participants) and the lack of technology-related subjects studied during their own education (five participants). Eva mentioned the following: "So, I would just attribute it a little bit to my own studies and the not much training, so to speak, and since I haven't learned very much about it in a didactic way, how I can teach it to the children." Another teacher, Stela, added: "Many feel so insecure and therefore do not want to pass this on to the children…when I am already unconfident myself, then I can't teach the topic to the children either…."

Additionally, four interviewees explained that a lack of time and their own school experience may also influence their competence in integrating technology. For instance, Natalie stated: "In practice it fails because you have no time to invest to educate myself to teach this subject…and I think because I have never experienced this technology lesson myself…" Three other interviewees mentioned their lack of teaching experience and of

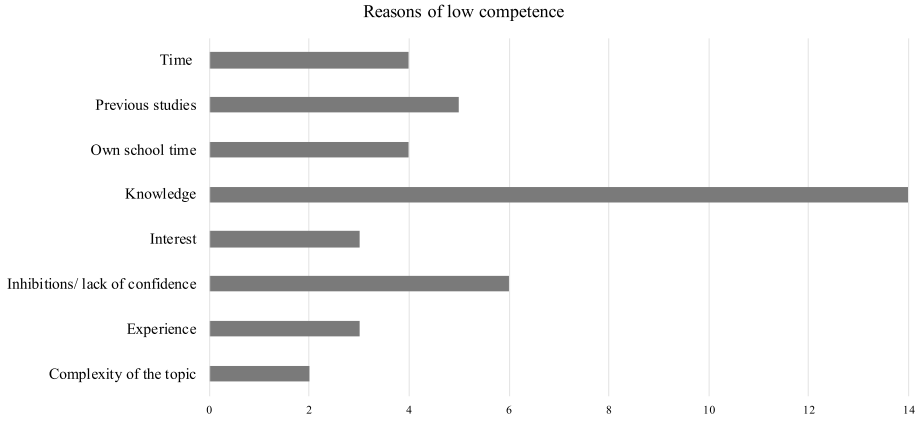

Fig. 1 Primary School Teachers' Reasons For Their Low Perceived Competence Regarding the Integration of Technology

interest in technology-related topics. Laura said: "Because so far it's definitely not an area that has greatly interested me. And at the end of the day, it's the same for me as it is for the children, I like to learn what I'm interested in."

However, six female participants stated that they did feel relatively competent in integrating technology topics into their lessons. Five of them expressed that their perceived competence could be attributed to their own motivation about the subject. For example, Anna mentioned: "I think once I understand that, I put my heart into it and then I'm competent to bring it to the students." Another interviewee, Petra, added: "Because I me myself find technology-related topics most interesting and exciting, I can also discuss them in depth with the children." Additionally, two teachers expressed that technology was a part of their own studies and therefore they felt competent integrating this subject into their lessons.

Teachers' perceived support in the integration of technology education

We identified four categories of aspects influencing primary school teachers' perceived support in the integration of technology: materials and equipment, extra personnel, the addition of technology topics into their studies, as well as the addition of technology topics to the curricula. Regarding possible types of support, two categories were determined based on teachers' answers: external providers, as well as colleagues and the teaching community. The majority of the primary school teachers (15 out of 21) expressed that they did not feel supported in integrating technology-related topics into their lessons. Five teachers mentioned that they felt supported, while one interviewee indicated that she did not know where or from whom to ask for support.

According to the participants, the following could influence their perceived support: the materials and equipment available to plan their lessons (four participants), having a second teacher in the classroom when including hands-on activities (two participants), and the inclusion of technology topics in their studies and in the curriculum (two participants). For instance, Diana said: "So now in general through my studies and so in school and based on the schoolbook, I honestly don't feel great support there" Another interviewee, Elisa, added:

> Also, from the schoolbooks and the curriculum, we are also not necessarily supported, because technology subjects do not occupy a large area. You don't really have the time, because there are so many topics that you have to teach that you can't really deal with technology topics for longer periods.

Regarding the parties that could provide support, 11 teachers said that they mostly receive support through external providers, such as professional development programs. Stela expressed: "So, in the last few years it's been getting better, because there are also external providers approaching the schools… We have also continued to network with further trainings and professional development programs." Nine participants mentioned that they could ask and get support from their colleagues and teaching community. For example, Kate said: "But I'm sure that there are also people in the community who are a bit more technologically competent and have more know-how, and that I can ask them about it."

Primary school teachers' perceptions of the current integration of and barriers to technology education

Current integration

The primary school teachers indicated four reasons for the low technology integration in their teaching practices: the pandemic, the broad curriculum, time, and safety concerns while working with technology related tasks. Seventeen interviewees expressed that during the last year, the level of integration of technology subjects was relatively low. Eleven teachers mentioned that one of the reasons for the low level of technology integration was the pandemic necessitating distance or virtual education. Additionally, seven teachers noted that the reason for low technology integration is the broad and undefined curriculum standards. For example, Maria said: "It is such a difficult thing, because in the curriculum it doesn't say exactly what and which topics have to be dealt with, but rather which areas should be covered." Paul added: "We have always postponed it, because it is unfortunately only a small part of the curriculum."

Two interviewees also mentioned the unclear curriculum teaching time frames for the subject. Maria noted: "The curriculum is always designed for two years, so in the first and second grade, you should have worked through these six areas, but of course there are areas that take a longer period of time and areas that take a shorter period of time, so how intensively you deal with them varies from teacher to teacher." Furthermore, two teachers noted safety concerns while working with technology related tasks, such as usage of tools and cables, electricity safety rules etc. Lena mentioned the following: "In general, safety is an important aspect in technology lessons, because somehow there are also possible dangers." Nevertheless, four teachers said that during the last year, the level of technology integration in their classrooms was relatively high.

Existing Barriers

The participants mentioned several existing barriers to the integration of technology in primary schools. After carefully reading the transcripts, the perceived barriers were identified, and 14 subcategories were determined (see Fig. 2). Primary school teachers noted

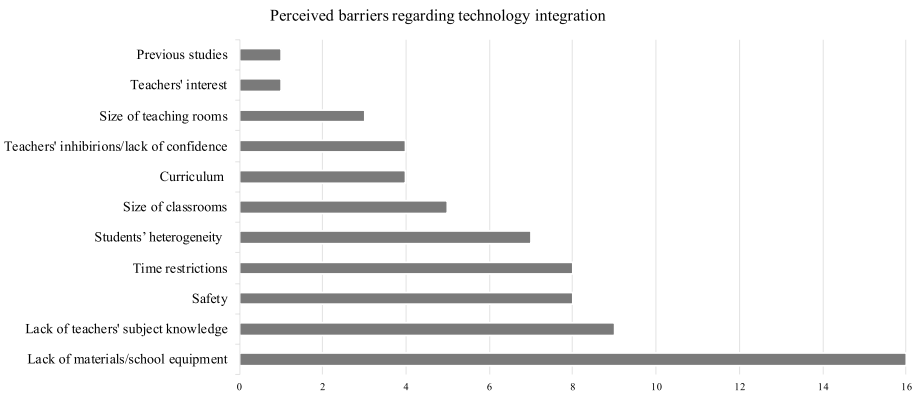

Fig. 2 Primary School Teachers' Perceived Barriers Regarding the Integration of Technology

that the most perceived barrier was the lack of materials and school equipment (16 participants), the lack of knowledge regarding technology related topics (nine participants), safety aspects (eight participants), time restrictions (eight participants), and students' heterogeneity (seven participants). Regarding the lack of materials and safety concerns, Diana mentioned the following: "For any hands-on approach…it's also often difficult that really the whole class does that and where the materials come from and what can you really do with the kids, what's safe…there are things I don't dare do because, I'm alone with twenty children and I think it's too dangerous…" Another interviewee, Laura, emphasized the lack of teachers' knowledge and training in technology education:

> I believe we lack the foundation and the necessary training…So I think I'm like a lot of teachers out there, who aren't that familiar with technology and therefore always deal with it quickly, or just take the things you have in the book and do it in good conscience, but ultimately don't have a deeper understanding of it.

The primary school teachers also considered the following to be barriers: the size of the classrooms (five participants), the broad curriculum (four participants), teachers' own inhibitions and lack of confidence regarding technology (four participants), the size of the teaching rooms (three participants), their own interest and educational background (one participant). The issues of time constraints and difficulties regarding the curriculum were addressed by Paul: "We only have very limited time, because our curriculum has many different areas, many of which are social." Another interviewee, Laura, emphasized the perceived inhibitions and lack of teachers' confidence about the subject of technology: "I think the case with many teachers is that with the topics that they themselves don't understand so well or they're simply not so confident, they don't focus on them on their teaching…because they could impart students' correct knowledge…"

Discussion

This study mapped the status quo of technology integration in primary schools, shedding light on primary school teachers' perceptions about the value of, barriers to, and received support in integrating technology-related topics into their lessons. Our findings indicated that primary school teachers place importance on the integration of technology-related subjects in their teaching. However, they mentioned that the level of technology integration, especially during the last year, was relatively low.

Overall teachers' responses reflected five main categories about the value of technology integration in primary schools. In line with previous studies regarding teachers' perceptions of STEM (Gibson, 2009; Margot & Kettler, 2019), most participants mentioned the everyday usage of and future need for technology as important reasons for technology integration. Additionally, children's early contact with technology and existing gender stereotypes were included among the five most prevalent reasons to value technology integration. Similar results were found in past studies, wherein teachers mentioned the importance of technology in counteracting gender stereotypes and motivational differences in STEM (Blümer, 2019; Mammes et al., 2016; Wright et al., 2018). Teachers also referred to the lack of technology-related topics in curricula despite their importance in students' current and future everyday life.

An important finding of this study relates to low technology integration, which depends upon a lack of standard and clear curriculum frameworks, as well as the challenge of the

undefined teaching time of the technology related topics in curricula. Lack of time, unclear curricula, and the challenge that technology-related topics are often included within the subject of "general science" are important reasons behind lower technology integration in schools (Koch et al., 2019; Mammes et al., 2016; Rasinen et al., 2009).

The discrepancies observed among the curricula and the lack of technology-oriented pre-service teacher training efforts across Germany (Blömeke et al., 2010; KMK, 2008; Mammes et al., 2016) were reflected in the primary school teachers' answers about their perceived competencies in technology integration. In detail, five teachers stated that during their studies, they did not have any technology-related subjects; furthermore, most teachers (14 out of 21) mentioned that they do not feel competent integrating technology-related topics into their teaching because they lack the necessary content knowledge and do not feel confident enough with their abilities. Similar results were reported in previous research, where findings revealed that technology integration is perceived as unclear and more challenging compared to science and mathematics (Gibson, 2009; Suwarma & Kumano, 2019; Wang et al., 2011). It is evident that lack of knowledge, clarity, and training may impact teachers' competence and confidence in technology integration (Mammes et al., 2012; Möller et al., 1996; Rohaan, 2009; Thibaut et al., 2019; Yoon et al., 2018). Our findings revealed that teachers' motivation for professional development, along with their pre-service training, were the main factors associated with high competence levels in technology integration.

As other studies have suggested, it is crucial for teachers to receive support from school structures, policies, and training efforts in order to feel motivated and to further develop their professional technology-related skills (Georgiou et al., 2020). Our findings showed that most teachers do not feel supported (15 out of 21), and they expressed the need for further support at the school level, such as the supply of the necessary materials and tools, along with the need for extra teaching staff. Aside from materials and resources, our participants mentioned the need for change in curricula in line with previous literature on STEM integration (Margot & Kettler, 2019), the inclusion of technology-related topics in pre-and in-service teacher training curricula, as well as the need for collaboration with their colleagues and the creation of teaching communities.

In addition to our findings on teachers' need for support, our participants mentioned several barriers to the integration of technology. Consistent with the existing literature on STEM integration (Chikasanda et al., 2011; Margot & Kettler, 2019; Park et al., 2017; Yu et al., 2021), most teachers referred to a lack of resources—namely, materials and school equipment (16 participants), lack of content knowledge (nine participants), time constraints (eight participants), and students' heterogeneity (seven participants). Our participants also referred to students' safety while working with tools and electricity (eight participants), the size of the classroom (five participants), the broad curriculum (four participants), and their self-inhibitions regarding technology (four participants).

Implications and future directions

This study is one of the few studies to explore and identify primary school teachers' perceptions when teaching technology-related subjects. Our results revealed four key factors for fostering the integration of technology —namely, the enhancement of primary school teachers' technology content knowledge, the improvement of these teachers' confidence in teaching technology, the need for further technology-oriented professional development

courses, and the need to incorporate technology-oriented curriculum standards. Our study contributes to the scarce literature in technology education in primary schools by establishing a knowledge base for teachers' needs about the integration of technology, which could benefit both research and practice in technology education.

Regarding the practical implications, future efforts on professional development programs could include activities to foster teachers' technology content knowledge by introducing practical workshops with hands-on activities to increase teachers' confidence and reduce their safety inhibitions while working with technology. For instance, clarity in technology curricula aims along with suggestions for the necessary teaching time and material development for technology-related activities could support teachers and simplify their efforts on technology integration in their teaching practices. Additionally, school and state representatives should reflect on teachers' needs for clear curriculum frameworks with concrete aims and implementation processes. School and state representatives must acknowledge the need for school equipment and materials to support teachers in properly integrating technology-related lessons in primary schools. Our findings could also encourage school principals to organize school intern trainings and technology-related activities to address teachers' need for support and foster collaboration among colleagues. A dedicated space with the necessary materials for technology activities could also be established in schools to promote and support teachers' efforts in the integration of technology.

Based on the findings of this study, we are currently developing a professional development course to enhance the integration of technology in German primary schools. Our future research and the professional development course aim to help bridge the gap between theory and practice in this field by supporting concrete curriculum aims and incorporating hands-on activities with concrete implementation strategies and lesson concepts. We have built upon the knowledge base provided by this study and aim to motivate, prepare, and support teachers during the development and integration of technology lessons in primary schools.

Limitations

While this study presents important findings, there are some limitations that need to be addressed. Our study focused on primary school teachers' perceptions and experiences with technology use in Bavarian schools, which may limit the generalizability of our findings due to differences in curricula among all German states (Mammes et al., 2016). However, our aim, as in other qualitative studies (e.g.,Georgiou et al., 2023), was not to generalize our findings to a larger population but to provide a rich and contextualized understanding of primary school teachers' perceptions and experiences with technology integration.

We followed a constructivist approach that values individual perspectives and experiences in shaping these perceptions (Creswell & Poth, 2016). Nonetheless, to address this limitation, we purposively selected a diverse group of primary school teachers and used rigorous data analysis methods to ensure the trustworthiness of our results. Given the exploratory nature of our study, future research could aim to replicate our findings with more diverse samples of primary school teachers from different regions to explore potential similarities and differences.

Conclusion

In summary, the current study explored primary school teachers' technology-related implementation practices, perceived value of technology education, and perceived challenges and support needs. Our findings highlighted the essential determinants for the integration of technology—namely, teachers' technology content knowledge, confidence, need for training, and need for clarity in curriculum standards. This study builds the knowledge base necessary to promote future efforts to successfully standardize curricula frameworks and to develop and implement technology-oriented professional development programs for pre-and in-service primary school teachers.

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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.

References

Bell, D. (2016). The reality of STEM education, design and technology teachers' perceptions: A phenomenographic study. *International Journal of Technology and Design Education, 26*(1), 61–79. https://doi.org/10.1007/s10798-015-9300-9

Blömeke, S., Kaiser, G., & Lehmann, R. (2010). *TEDS-M 2008. Professionelle Kompetenz und Lerngelegenheiten angehender Primarstufenlehrkräfte im internationalen Vergleich*. [Professional competence and learning opportunities of prospective primary teachers in international comparison]. Waxmann Verlag.

Blümer, H. (2019). Die technische Bildung im Sachunterricht an deutschen Grundschulen. Technology education in social studies and science at German elementary schools In *Zur Bedeutung der Technischen Bildung in Fächerverbünden*. pp 1–13 Springer

Boeve-de Pauw, J., Ardies, J., Hens, K., Wullemen, A., van de Vyver, Y., Rydant, T., De Spiegeleer, L., & Verbraeken, H. (2020). Short and long term impact of a high-tech STEM intervention on pupils' attitudes towards technology. *International Journal of Technology and Design Education, 32*, 825–843. https://doi.org/10.1007/s10798-020-09627-5

Bozick, R., Srinivasan, S., & Gottfried, M. (2017). Do high school STEM courses prepare non-college bound youth for jobs in the STEM economy? *Education Economics, 25*(3), 234–250. https://doi.org/10.1080/09645292.2016.1234585

Brenner, M. (2006). Interviewing in educational research. In: J. L. Green, G. Camilli, G. & P. B. Elmore (Eds.), *Handbook of complementary methods in education research* (p. 357-370). Washington, DC: Routledge.

Çengel, M., Alkan, A., & Yildiz, E. P. (2019). Evaluate the attitudes of the pre-service teachers towards STEM and STEM's sub dimensions. *International Journal of Higher Education, 8*(3), 257–267. https://doi.org/10.5430/ijhe.v8n3p257

Chikasanda, V. K., Otrel-Cass, K., & Jones, A. (2011). Teachers' views about technical education: Implications for reforms towards a broad based technology curriculum in Malawi. *International Journal of Technology and Design Education, 21*(3), 363–379. https://doi.org/10.1007/s10798-010-9125-5

Creswell, J. W., & Poth, C. N. (2016). *Qualitative inquiry and research design: Choosing among five approaches,* Sage publications.

Davies, R. S. (2011). Understanding technology literacy: A framework for evaluating educational technology integration. *TechTrends, 55*(5), 45–52. https://doi.org/10.1007/s11528-011-0527-3

Davies, T. (2000). Confidence! Its role in the creative teaching and learning of design and technology. *Journal of Technology Education, 12*(1), 18–31. https://doi.org/10.21061/jte.v12i1.a.2

De Vries, M. (2000). Can we train researchers and teachers to make a team? Win–win strategies in technology education. *Proceedings of the first biennial international conference on technology education research.* (pp. 1–12). Griffith University.

de Vries, M. (2019). Technology Education in the Context of STEM Education. *Zur Bedeutung der Technischen Bildung in Fächerverbünden* (pp. 43–52). Berlin: Springer.

Firat, M. (2017). Growing misconception of technology: Investigation of elementary students' recognition of and reasoning about technological artifacts. *International Journal of Technology and Design Education, 27*(2), 183–199. https://doi.org/10.1007/s10798-015-9351-y

Georgiou, D., Mok, S. Y., Fischer, F., Vermunt, J. D., & Seidel, T. (2020). Evidence-based practice in teacher education: The mediating role of self-efficacy beliefs and practical knowledge. In *Frontiers in education* (Vol. 5, pp. 559192). Frontiers Media SA.

Georgiou, D., Diery, A., Mok, S. Y., Fischer, F., & Seidel, T. (2023). Turning research evidence into teaching action: Teacher educators' attitudes toward evidence-based teaching. *International Journal of Educational Research Open, 4*, 100240. https://doi.org/10.1016/j.ijedro.2023.100240

Gibson, K. (2009). Technology and design, at key stage 3, within the Northern Ireland curriculum: Teachers' perceptions. *International Journal of Technology and Design Education, 19*(1), 37–54.

Hammack, R., & Ivey, T. (2019). Elementary teachers' perceptions of K-5 engineering education and perceived barriers to implementation. *Journal of Engineering Education, 108*(4), 503–522. https://doi.org/10.1002/jee.20289

Jakobs, E.-M., & Ziefle, M. (2010). *Wege zur Technikfaszination: Sozialisationsverläufe und Interventionszeitpunkte*. [Pathways to technology fascination: socialization trajectories and intervention points]. Springer-Verlag.

Kallio, H., Pietilä, A. M., Johnson, M., & Kangasniemi, M. (2016). Systematic methodological review: Developing a framework for a qualitative semi-structured interview guide. *Journal of Advanced Nursing, 72*(12), 2954–2965. https://doi.org/10.1111/jan.13031

Keskin, T. (2017). The Technology in the Programs of Life Sciences in Turkey and Sachunterricht in Germany. *International Technology and Education Journal, 1*(1), 10–15.

KMK. (2008). Ländergemeinsame inhaltliche Anforderungen für die Fachwissenschaften und Fachdidaktiken in der Lehrerbildung. [State-specific content requirements for the subject areas of science and didactics in teacher education]. Sekretariat der Ständigen Konferenz der Kultusminister der Länder in der Bundesrepublik Deutschland: Lehrerbildung in Deutschland-Standards und inhaltliche Anforderungen.

Koch, A. F., Kruse, S., & Labudde, P. (2019). *Zur Bedeutung der Technischen Bildung in Fächerverbünden*. Springer: The importance of technical education in subject groups. https://doi.org/10.1007/978-3-658-25623-4

Korstjens, I., & Moser, A. (2018). Series: Practical guidance to qualitative research Part 4: Trustworthiness and publishing. *European Journal of General Practice, 24*(1), 120–124. https://doi.org/10.1080/13814788.2017.1375092

Landwehr, B., Mammes, I., & Murmann, L. (2021). *Technische Bildung im Sachunterricht der Grundschule: Elementar bildungsbedeutsam und dennoch vernachlässigt?* Technology Education in Primary School: Fundamental Educational Importance and Yet Neglected. Verlag Julius Klinkhardt.

Mammes, I., Schaper, N., & Strobel, J. (2012). Professionalism and the Role of Teacher Beliefs in Technology Teaching in German Primary Schools–An Area of Conflict. *Teachers' Pedagogical Beliefs*, 91.

Mammes, I., Fletcher, S., Lang, M., & Münk, D. (2016). Technology Education in Germany. In *Technology Education Today. International Perspectives.* (pp. 11–38). Waxmann Verlag.

Mammes, I. (2014). Zum Einfluss früher technischer Bildung auf die Identitätsentwicklung tu–Zeitschrift für Technik im Unterricht The influence of early technical education on identity development. *Frühe Technische Bildung, 151*(1), 5–11.

Mammes, I., Adenstedt, V., Gooß, A., & Graube, G. (2019). Technology Information Technology and Natural Science as Basics for Innovation. *Zur Bedeutung der Technischen Bildung in Fächerverbünden* (pp. 93–109). Berlin: Springer.

Margot, K. C., & Kettler, T. (2019). Teachers' perception of STEM integration and education: A systematic literature review. *International Journal of Stem Education, 6*, 16. https://doi.org/10.1186/s40594-018-0151-2

McHugh, M. L. (2012). Interrater reliability: The kappa statistic. *Biochemia Medica, 22*(3), 276–282.

McLellan, E., MacQueen, K. M., & Neidig, J. L. (2003). Beyond the qualitative interview: Data preparation and transcription. *Field Methods, 15*(1), 63–84. https://doi.org/10.1177/1525822X02239573

McMullin, K., & Reeve, E. (2014). Identifying perceptions that contribute to the development of successful project lead the way pre-engineering programs in Utah. *Journal of Technology Education, 26*, 22–46. https://doi.org/10.21061/jte.v26i1.a.2

Milne, L. (2013). Nurturing the designerly thinking and design capabilities of five-year-olds: Technology in the new entrant classroom. *International Journal of Technology and Design Education, 23*(2), 349–360. https://doi.org/10.1007/s10798-011-9182-4

Möller, K., Tenberge, C., & Ziemann, U. (1996). Technische Bildung im Sachunterricht. *Eine quantitative Studie zur Ist-Situation an nordrhein-westfälischen Grundschulen.* [Technology Education in the Classroom. A quantitative study of the current situation at primary schools in North Rhine-Westphalia]. *Münster: Selbstverlag*.

Möller, K. (2010). Naturwissenschaftliche und technische Bildung in der Grundschule und im Übergang. [Science and technology education in primary school and the transition]. *A. a Campo & G. Graube (Hrsg.), Übergänge gestalten. Naturwissenschaftliche und technische Bildung am Übergang von der Primarstufe zur Sekundarstufe (S. 15–35). Düsseldorf: VDI.*

O'Connor, C., & Joffe, H. (2020). Intercoder reliability in qualitative research: debates and practical guidelines. *International Journal of Qualitative Methods, 19*, 1609406919899220. https://doi.org/10.1177/1609406919899220

Park, M.-H., Dimitrov, D. M., Patterson, L. G., & Park, D.-Y. (2017). Early childhood teachers' beliefs about readiness for teaching science, technology, engineering, and mathematics. *Journal of Early Childhood Research, 15*(3), 275–291. https://doi.org/10.1177/1476718X15614040

Rasinen, A., Virtanen, S., Endepohls-Ulpe, M., Ikonen, P., Ebach, J., & Stahl-von Zabern, J. (2009). Technology education for children in primary schools in Finland and Germany: Different school systems, similar problems and how to overcome them. *International Journal of Technology and Design Education, 19*(4), 367–379. https://doi.org/10.1007/s10798-009-9097-5

Rohaan, E. J. (2009). Testing teacher knowledge for technology teaching in primary schools. *Printservice TU/e*. https://doi.org/10.6100/IR653226

Ropohl, G. (1991). *Technologische Aufklärung Beiträge Zur Technikphilosophie*. [Technology Enlightenment Contributions to the Philosophy of Technology]. Suhrkamp Verlag.

Ropohl, G. (2009). *Allgemeine technologie: eine systemtheorie der technik*. [General technology: a systematic theory of technology]. KIT Scientific Publishing.

Rossouw, A., Hacker, M., & de Vries, M. J. (2011). Concepts and contexts in engineering and technology education: An international and interdisciplinary Delphi study. *International Journal of Technology and Design Education, 21*(4), 409–424. https://doi.org/10.1007/s10798-010-9129-1

Schreier, M. (2012). *Qualitative content analysis in practice*. Sage publications.

Sherman, T. M., Sanders, M., & Kwon, H. (2010). Teaching in middle school Technology Education: A review of recent practices. *International Journal of Technology and Design Education, 20*(4), 367–379. https://doi.org/10.1007/s10798-009-9090-z

Sultan, U. N., Axell, C., & Hallström, J. (2020). Technical or not? Investigating the self-image of girls aged 9 to 12 when participating in primary technology education. *Design and Technology Education: An International Journal, 25*(2), 175–191.

Suwarma, I., & Kumano, Y. (2019). I Implementation of STEM education in Indonesia: Teachers' perception of STEM integration into curriculum. *Journal of Physics: Conference Series.* (Vol. 1280, No. 5, p. 052052). IOP Publishing.

Thibaut, L., Knipprath, H., Dehaene, W., & Depaepe, F. (2019). Teachers' attitudes toward teaching integrated STEM: The impact of personal background characteristics and school context. *International Journal of Science and Mathematics Education, 17*(5), 987–1007. https://doi.org/10.1007/s10763-018-9898-7

Wammes, D., Slof, B., Schot, W., & Kester, L. (2022). Teacher judgement accuracy of technical abilities in primary education. *International Journal of Technology and Design Education*, 1–24. https://doi.org/10.1007/s10798-022-09734-5

Wang, H.-H., Moore, T. J., Roehrig, G. H., & Park, M. S. (2011). STEM integration: Teacher perceptions and practice. *Journal of Pre-College Engineering Education Research J-PEER, 1*(2), 2. https://doi.org/10.5703/1288284314636

Wender, I. (2004). Relation of technology, science, self-concept, interest, and gender. *Journal of Technology Studies, 30*(3), 43–51.

Wright, G. A., Reeves, E., Williams, J., Morrison-Love, D., Patrick, F., Ginestié, J., Mammes, I., & Graube, G. (2018). abridged international perspectives of technology education and its connection to stem education. *International Journal of Education, 10*(4), 31–56. https://doi.org/10.5296/ije.v10i4.13704

Yoon, S. Y., Kong, Y., Diefes-Dux, H. A., & Strobel, J. (2018). Broadening K-8 teachers' perspectives on professional development in engineering integration in the United States. *International Journal of Research in Education and Science, 4*(2), 331–348. https://doi.org/10.21890/ijres.409263

Yu, K.-C., Wu, P.-H., Lin, K.-Y., Fan, S.-C., Tzeng, S.-Y., & Ku, C.-J. (2021). Behavioral intentions of technology teachers to implement an engineering-focused curriculum. *International Journal of Stem Education, 8*(1), 1–20. https://doi.org/10.1186/s40594-021-00305-z