The Role of Teacher's Knowledge in Promoting Task-Technology Fit for Early Childhood and Inclusive Technology-Based STEM Instruction

Arkhadi Pustaka, Sampoerna University, Indonesia
Christianus I Wayan Eka Budiartha, Sampoerna University, Indonesia
Ibifuro Ken-Giami, Centre for Economic and Leadership Development, United Kingdom
Sarinova Simandjuntak, Anglia Ruskin University, United Kingdom

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Abstract
In technology-based STEM instruction, teachers' knowledge of how technology is being used in the instruction is crucial to initiate meaningful learning activities, particularly in early childhood and inclusive education. The objective of this research is to explore the teacher's belief in understanding technology characteristics and their attitudes toward task characteristics to introduce STEM in their classrooms. Drawing on a systematic literature review, which emphasized the significance of both task and technology characteristics, a qualitative study was conducted as part of the British Council Game-Based Learning for STEM education project. 52 teachers from greater Jakarta, Indonesia were engaged in a focus group discussion to explore their beliefs and practices in fostering STEM instruction through technology. The results show that even though the participants have a good understanding and positive attitude towards technology, they need more support in acquiring and adopting suitable technology for their pedagogical practices. The findings of this study have important implications for the design and the use of technology in early childhood and inclusive education STEM instruction.

Keywords: Teachers' Knowledge, Task-Technology Fit, STEM Learning, Early Childhood Education

Introduction

The year 2007 etched itself not only in tech history but also, potentially, in the annals of education. Coinciding with Apple's revolutionary iPhone launch, the Programme for International Student Assessment (PISA) began registering a global decline in student performance (Schleicher, 2019). While causation can't be established with certainty, the correlation raises a critical question: in the age of ubiquitous smartphones, does the use of technology for entertainment purposes eclipse its use for learning leading to the decline of students' academic achievement? The answer, thankfully, isn't a binary Yes or No. It lies in a nuanced interplay between fostering responsible technology use and harnessing its potential to ignite meaningful learning, particularly in STEM (Science, Technology, Engineering, and Mathematics) fields for early childhood and inclusive education.

Recent studies conducted by PISA point towards excessive technology use for leisure as a potential factor impeding academic performance (OECD, 2023). Social media notifications, endless game worlds, and the alluring whirlpool of online distractions can undoubtedly siphon off focus and study time. However, demonizing technology as the sole culprit would be remiss. Smartphones and tablets, when wielded wisely, hold immense potential to propel STEM learning. Consider an interactive app that brings the vibrant rainforest onto a child's screen, sparking curiosity about ecological wonders. Or imagine a game that challenges young minds to build virtual bridges, igniting an early passion for engineering principles. Such thoughtfully designed technology can transform learning from passive absorption to active exploration.

This is where the role of teachers becomes paramount. In a technology-infused classroom, educators shift from mere providers of information to skilled orchestrators of a dynamic learning symphony (Etmer & Ottenbreit-Leftwich, 2010). Their knowledge of how technology integrates with the curriculum becomes crucial. A teacher adept at utilizing virtual reality simulations to delve into the human body can make anatomy lessons come alive for even the youngest learners. Similarly, an instructor who leverages educational coding platforms can introduce programming concepts in a fun and accessible way, fostering a future generation of tech-savvy citizens. Hence, studying teachers' knowledge about technology through the lens of task-technology fit (TTF) is crucial.

The TTF framework provides a nuanced understanding of how well a technology aligns with the specific learning goals and activities in a given context (Goodhue & Thompson, 1995). It moves beyond mere access to gadgets, delving into how teachers leverage features, troubleshoot challenges, and adapt technology to meet the diverse needs of their students. Examining teacher knowledge through this framework reveals not just their technical proficiency, but their pedagogical insights and ability to orchestrate meaningful technology-enhanced learning experiences.

Studying teacher knowledge in this context also equips us to bridge the gap between the promise of technology and its actual impact in classrooms. The "fit" is not static; it's a dynamic interplay between teacher expertise, student engagement, and the evolving nature of digital tools. By understanding how teachers perceive, evaluate, and integrate technology within their tasks, we can design better professional development programs, curate resources that resonate with their teaching styles, and ultimately, foster environments where technology complements, rather than dominates, the learning process.

Promoting TTF within early childhood and inclusive STEM instruction requires a nuanced approach. While standardized, top-down models may offer a degree of efficiency, they often fail to account for the unique needs and contexts of individual classrooms. Therefore, a bottom-up approach that leverages the knowledge and expertise of teachers is needed.

There are two main reasons why a bottom-up approach is best suited for our purposes. Firstly, due to the dynamic nature of early childhood education and the diverse needs of students, a one-size-fits-all technology implementation wouldn't be effective. Teachers, being in the school with the students, are best positioned to identify specific learning goals and tailor technology use accordingly. Secondly, fostering a sense of agency among teachers is essential. By empowering them to select and integrate technologies that align with their instructional practices, we promote ownership and a deeper understanding of how technology can enhance learning outcomes.

This bottom-up approach necessitates a strong understanding of our teachers' knowledge and comfort levels with technology. Through open communication, professional development focused on TTF principles, and collaborative exploration of technological tools, we can equip teachers to make informed decisions about technology integration. By prioritizing the teacher's role in achieving TTF, we create a more effective and inclusive STEM learning environment for young children.

Task Technology Fit

The TTF framework, proposed by Goodhue and Thompson in 1995, examines the relationship between a specific task and the technology designed to support it. It essentially asks how well the technology matches the demands of the task. This seemingly simple question holds significant weight in optimizing user experience and performance.

According to Goodhue and Thompson (1995), a good TTF is achieved when a technology's capabilities align with the requirements of the task. This fit can be assessed from two main perspectives: task characteristics and technology characteristics.Task characteristics encompass the nature of the work, such as complexity, repetitiveness, and the need for information processing. Technology characteristics, on the other hand, focus on the features and functionalities the technology offers.

For example, a data analyst working with complex datasets would benefit from a technology that provides robust data manipulation and visualization tools. Conversely, a customer service representative taking simple inquiries might find the same technology cumbersome and time-consuming. TTF emphasizes that a one-size-fits-all approach to technology doesn't work. Organizations that prioritize TTF ensure their chosen technologies effectively address user needs, ultimately leading to increased efficiency, user satisfaction, and improved performance.

The TTF framework provides a valuable lens for examining the role of teacher knowledge in early childhood STEM education. TTF emphasizes the importance of aligning technology capabilities with the specific demands of a learning task. In this context, teachers act as crucial actors in understanding these task demands. Their knowledge of student needs, learning styles, and classroom dynamics informs their technology preferences. The body of literature on the topic of teachers’ preference for tangible tools that promote the use of technology to deliver STEM education showed that the concept of mediating artifacts is crucial to understanding this topic (Scanlon et al., 2019; Abrahamson & Lindgren, 2014; Guribye, 2015; Damşa, 2014; Tchounikine, 2016; Sinha et al., 2015). These artifacts, whether digital or non-digital, bridge the gap between learners and abstract concepts. By understanding teachers' preferences for technological tools, we gain valuable insights into how technology can best function as a mediating artifact within the classroom and promote successful learning.

Mediating artifacts are regarded as tools that contribute to the facilitation and mediation of human activities and interaction (Guribye, 2015; Scanlon et al., 2019). Although related to the concept of computer-supported cooperative work (CSCW), which is the study of the fundamental role of computer systems in reducing complex activities (Schmidt & Simonee, 1996), mediating artifacts are also utilized in different contexts including aiding teachers' facilitation of learning and knowledge or skills mastery (Guribye, 2015; Braseth, 2021). In such classroom contexts, it has been shown that these artifacts could take the form of physical objects, such as tools or technologies, or textual forms such as symbolic represents and textbook tasks (Schiepe-Tiska et al., 2021; Sinha et al., 2015).

Additionally, the majority of the literature reviewed in this study highlighted a wide range of both technology-mediated and textual artifacts being utilized by STEM teachers to enhance their teaching. For instance, the adopted textual mediating artifacts included textbooks and instructional materials (Stains et al.,2018; Kelley & Knowles, 2016), lab manuals and experiment protocols (Van den Broek, 2010; Ghavifekr & Rosdy, 2015), and textual prompts and cues (Xie et al., 2015; Drijvers et al., 2020). The adopted technology-mediated artifacts on the other hand, included digital devices, sensors, data loggers, whiteboards, and other educational software and applications (Juškevičienė et al., 2020; Karahan et al., 2015; Gillen et al., 2007). However, there is an ongoing argument about which of the two types of mediating artifacts would better enhance STEM teachers' transfer of knowledge to students and allow for a more effective teaching approach (Vicente et al., 2022; Viberg et al., 2020; Koehler et al., 2013).

Nevertheless, the importance of both categories of artifacts in providing students with the opportunity to collaborate and explore diverse concepts remains fundamental in advancing STEM competencies across all fields. Likewise, there seems to be a unified perspective about the crucial role of both mediating artifacts in TTF Instruction. It has been suggested that achieving a synergy between both artifacts is imperative to facilitating the alignment between the assigned tasks and selected technology. Such a combination, therefore, contributes to bridging the gap between the task requirements and the technology capabilities to ensure that the latter effectively supports the former (Vanduhe et al., 2020; Webster & Hackley, 1997).

The overall findings can be summarised in the table below.

Table 1. Summary of Literature Review on TTF in STEM Learning

Thematic Category (preferred tool to deliver STEM education)	**Purpose**	**Is the preferred tool more related to task or technology characteristics?**	**References**
Instructional materials (such as textbook tasks, worksheets and handouts, lab manuals, and experiment protocols)	To provide structured information and explanations of STEM concepts that guide lessons, experiment protocols, and provide targeted content and examples applicable to the specific discipline	Task characteristics	Stains et al. (2018); Vicente et al. (2022); Schiepe-Tiska et al. (2021)
Educational software and applications & ICT (simulations, virtual labs, interactive learning platforms, interactive whiteboards, and educational games)	To afford opportunities for students to explore and experiment with STEM concepts in a virtual environment, thereby fostering engagement and understanding	A blend of Technology and Task Characteristics	Alan et al. (2023); Juškevičienė et al. (2020); Karahan et al. (2015); Gillen et al. (2007)
Digital devices and tools (laptops/i-Pads, etc.); Diagnostic assessment and skill practice (IXL, i-Ready Math)	To strengthen students' learning experience as well as measure and track student growth	A blend of Technology and Task Characteristics	Hover & Wise (2020); Makamure & Tsakeni (2020); Kier & Khalil (2018); Hardcastle, Herrmann-Abell, and DeBoer (2017)
Textual prompts and cues (in the form of questions, prompts for reflection, or sentence starters that aid students' responses)	To guide students' thinking and accelerate their understanding of STEM concepts.	Task characteristics	Vedora & Conant (2015); Xie et al. (2015); Van den Broek (2010); Finkel & Williams (2001)
Manipulatives or hands-on materials (such as blocks, puzzles, engineering design kits, etc.)	To help students engage in problem-solving, design thinking, and collaborative projects.	A blend of Technology and Task Characteristics	Roslina et al. (2022); Garden (2022); Freeman et al. (2014)

Focus Group Discussion

To understand the role of teachers' knowledge in promoting TTF for early childhood and inclusive technology-based STEM instruction, this research is guided by three research questions: 1) What is the state of teachers' general knowledge of using educational technology for classroom activities? 2) How do teachers perceive the importance of using technology for students to accomplish their learning tasks? 3) How can teacher knowledge, beliefs, and attitudes be leveraged to promote task-technology fit (TTF) in technology-based STEM instruction?

Focused group discussions (FGDs) with 52 teachers from the Greater Jakarta Area, Indonesia, were conducted to answer those questions on March 16, 2023. The participants filled in a general information survey and informed consent statement. After that, they went to seven break-out rooms to have the FGDs facilitated by faculties from Sampoerna University. Each group consists of seven to eight discussion participants. The FGDs were recorded and transcribed in Bahasa Indonesia (Indonesian Language). The recordings were then analyzed qualitatively to draw out the essence of participants' knowledge.

Figure 1. FGD documentations

The majority of the participants are early childhood teachers (73%), followed by upper primary (i.e. elementary school grade 4/5/6) teachers (13%), lower primary (i.e. elementary school grade 1/2/3) teachers (8%), and middle school teachers (6%). Since the participants were mostly early childhood teachers, they taught all subject matters (58%) in a thematic format as mandated by the curriculum. However, small portions of the participants specifically teach Bahasa Indonesia (17%), physical education (11%), math (6%), and a variety of subjects (8%) which include, but are not limited to, informatics, religion, and local language (i.e. Bahasa Sunda/Sundanese Language). In terms of teaching tenures, the participants consist of experienced teachers (54%) with 7-15 years experience of teaching, novice teachers (35%) with 0-6 years experience of teaching, and senior teachers (11%) with more than 15 years experience of teaching.

Results

The FGDs provided valuable insights into teachers' knowledge and perspectives on promoting TTF within early childhood and inclusive STEM instruction. Here are the key findings:

Broad Understanding of Technology. Contrary to potential assumptions, the discussions revealed that most teachers possess a solid understanding of the role of technology in the classroom. Notably, they recognized that technology encompasses not only digital tools but also non-digital resources. The results of the general information survey showed that 84.6% of the participants use smartphones to facilitate learning and 82.7% of the participants use traditional teaching realia (non-digital technology). The teachers even have a common vocabulary for indoor teaching realia, loose parts, and outdoor teaching realia that they call

Alat Peraga Edukasi (APE). This broad understanding positions them well to make informed decisions about technology integration.

As an example of how technology-informed the teachers were, participant X commented: "*Kita buat modul dan video pembelajaran bersama dan dikumpulkan di Google Classroom*" that can be translated into "We made learning modules and videos together and collected (them) in Google Classroom." Some teachers also made learning materials for their students using Canva and uploaded them on TikTok. When asked from whom they learned to do that, they answered that they watched YouTube tutorials. They also believed that technology was an important part of their classroom. Their attitude towards technology use was 4.54 on a scale of 1 to 5. It means the teachers had a very positive attitude towards technology use in the classroom.

However, they also voiced a call for support. Only 67.3% of them get the Internet provided by the school. Many participants shared their stories of how hard it was to get an Internet connection during the pandemic. The majority of the FGD participants came from underprivileged communities. Hence, it was apparent that there were gaps in terms of the availability and access to the technology. Support was also needed regarding continuous professional development as shown in Figure 2.

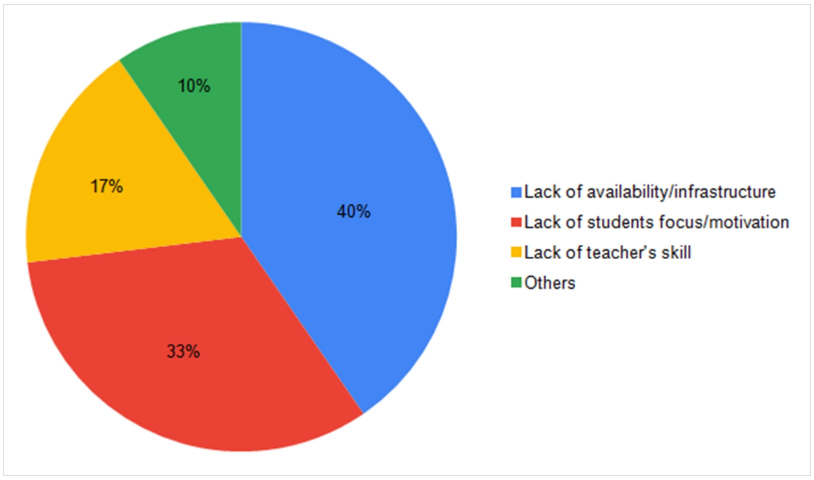

Figure 2. The area of problems where the teachers need support

Concerns Regarding Digital Technology. A recurring theme in the discussions was teachers' concerns about the potential negative impacts of digital technology on young learners. These concerns centered around issues like reduced attention span, social behavior problems, and the habit of instant gratification fostered by some digital interactions. This highlights the importance of selecting digital technologies that actively engage students and promote deeper learning experiences, rather than simply providing instant rewards.

For example, participant BP7 commented:

> "*Kalau dari Youtube itu bahasa anak-anak itu haduuh… Karena hasil dari tontonan, bahasa-bahasa gaul, meme yang viral itu, misal gurunya tanya ada yang mau bertanya dijawab anaknya 'kamu nanyea'.*"

That is translated into:

> "For example the language/attitude that the children acquired from YouTube *exclamation*… Because of the results of what they watch, slang language, and viral memes, when a teacher asks if they have a question, the students reply 'Are you asking me?'" (with attitude and impolite manner)

Emphasis on Movement-Based Learning. The discussions revealed a strong preference among teachers for technology that encourages student movement. This aligns with the established importance of physical activity in early childhood development. Technologies that integrate movement into learning activities can create a more engaging and developmentally appropriate STEM experience for young children.

For example, participant CP1 commented:

> "*... kalo jaman pandemi, yang sulit olahraga, karena suruh anak-anak bergerak tapi diluar jangkauan kita.Tidak bisa lihat mereka salah atau tidak. Pandemi itu benar-benar tantangan ...*"

That is translated into:

> "... the most challenging thing during the pandemic was physical education because we wanted the students to move but could not monitor them. We could not see whether the students did it correctly. The pandemic was indeed a challenging time ..."

Another example, participant MP5 commented:

> "*Nah, anak PAUD itu suka yang ada peraganya, sesuatu yang dia pegang, taktil, motorik, seperti playdoh, gunting-gunting, tempel-tempel itu mereka senang sekali. Lalu misal untuk tema air, udara, api, kita bisa pakai lilin ditutup — kita tanya itu kenapa begitu? Jadi anak itu harus melihat langsung, sesuatu yg konkrit.*"

That is translated into:

> "Ok, early childhood students like a demonstration, something they can touch, tactile, motoric, like playdough, cutting papers, stickers, those things they like a lot. And then for the theme of water, air, and fire, we can use candles to blow — we then ask, how can that be? So the children have to see it directly, something concrete."

Discussion

It can be implied from the results of the FGDs that there are two prominent essences of participants' knowledge regarding TTF. The participants' first voice is "I know what technology is, but I need some support." As shown in the results section, teachers understand the broad scope of technological tools but sometimes the tool is unavailable or inaccessible. Therefore, responsible stakeholders like the government, the industry, or the universities might need to provide the infrastructure, the tools, or the professional development to support the teachers.

Their second voice is “I believe technology is important, but I have some concerns.” Teachers’ concerns regarding technology use for children, among other things, are “How can we mitigate bad influences from their online activities/consumptions?”, “How can we mitigate the screen addiction risks if we introduce smartphones to children at an early age?”, “How can technology-based STEM instruction facilitate early childhood needs to move or to do physical activities?”, and “How can we bridge the gap between digital and non-digital technology?” Those questions implied that in promoting TTF, teachers are more drawn towards the task than what kind of available technology is to them. This aligns with the literature review on TTF for STEM learning mentioned earlier.

Those essences underscore the value of a bottom-up approach to TTF in early childhood STEM education. By recognizing teachers' existing knowledge base, addressing their concerns about digital tools, and incorporating movement-based learning opportunities, we can create a framework that fosters effective technology integration that aligns with the unique needs of early learners.

Conclusion

In answering the first research question regarding the state of teachers’ general knowledge of using educational technology for classroom activities, we can say that it is good. They understand that technology is a broad term encompassing digital and non-digital technology. Their skills, however, are open for further development.

Regarding how teachers perceive the importance of using technology for students to accomplish their learning tasks, the answer is positive albeit they have concerns about some risk factors. This attitude further confirms that teachers do not take their teaching job lightly. They do care and are concerned about the well-being of their students. Hence, in integrating technology in the classroom, teachers weigh the task heavier than the affordances of the technology.

Finally, in answering how teachers’ knowledge, beliefs, and attitudes can be leveraged to promote task-technology fit (TTF) in technology-based STEM instruction, there are opportunities for the stakeholders (e.g. government agencies, universities, etc.) to support teachers either in providing continuous professional developments or access to the technology that fits into the problems on the field. The bottom-up approach is indeed the key. Listening to the needs of teachers and students in school is a must. As UNESCO (2023) suggested, technological solutions to educational problems should not be centered around the technology itself, but it has to be human-centered solutions.

While a bottom-up approach to promoting Task-Technology Fit (TTF) in early childhood STEM education may require significant investment in time, cost, and professional development resources, the potential benefits outweigh the challenges. This approach fosters a sense of agency among teachers, empowering them to leverage their knowledge and understanding of their students' needs to curate inclusive learning environments. The resulting technology integration might not be a one-size-fits-all standardized solution. However, it holds the power to be far more meaningful and responsive to the specific needs of each classroom. By prioritizing teacher knowledge and fostering their role in achieving TTF, we create a foundation for a more engaging, inclusive, and successful STEM learning experience for young children.

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Contact email: arkhadi.pustaka@sampoernauniversity.ac.id