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WHY DO I USE TECHNOLOGY? PROFILING MATHEMATICS TEACHERS' TECHNOLOGY-RELATED PEDAGOGICAL REASONING

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Abstract.

Recently, scholars have started unpacking teachers' technology-related decision-making via the conceptual lens of pedagogical reasoning. Addressing the need for more domain-specific studies, this qualitative interview study set out to explore the technology-related pedagogical reasoning (TPR) of secondary school mathematics teachers (n = 17). The findings indicate that math teachers predominately rationalize their technology use based on enhancement (e.g., visualizing abstract concepts, providing instant feedback, facilitating differentiation) and efficiency (e.g., streamlining classroom activities, reducing manual grading) motives. Three distinct profiles of TPR were identified among math teachers: *Efficiency Navigators*, primarily driven by efficiency reasons for using technology; *Learning Facilitators*, merging efficiency and enhancement rationales in their adoption of technology; and *Instructional Innovators*, underpinning their technology use based predominantly on enhancement and engagement motives. Future research directions are discussed considering these findings.

Keywords: Pedagogical Reasoning, TPACK, Technology Integration, Mathematics Education.

INTRODUCTION

Implementing technology in the classroom can create more engaging, practical and/or efficient teaching and learning processes (Kopcha et al., 2020). However, there is a gap between this potential and its actual adoption, as research shows that teachers in many educational systems rarely incorporate technology into their practices (Fraillon et al., 2020). In this vein, decades of research have underscored the importance of (a) developing teachers' technology-related knowledge bases, often using the TPACK model of Koehler and Mishra (2009), and (b) fostering teachers' dispositions towards technology (e.g., attitudes, self-efficacy). To further unpack the *why* and *how* of teachers' technology-mediated practices, scholars have recently shifted towards studying teachers' decision-making processes in the context of technology integration (Hofer & Harris, 2019; Kopcha et al., 2020). In this vein, renewed attention has been given to the concept of pedagogical reasoning (PR) to unpack teachers' technology integration. However, the knowledge base of technology-related pedagogical reasoning (TPR) is still limited (Hofer & Harris, 2019; Hughes et al., 2020), without domain-specific TPR studies. Hence, this study examines secondary school math teachers' PR for using technology in their classes and tries to ascertain potential differences among their TPR.

LITERATURE REVIEW

Pedagogical Reasoning

Pedagogical reasoning (PR) refers to the "thinking that underpins informed professional practice" (Loughran, 2019, p.4). Coined by Shulman (1987) in his 'Model of Pedagogical Reasoning and Action' (MPR&A), PR involves a dynamic process of six stages: comprehension, transformation, instruction, evaluation, reflection, and new comprehension. Forkosh-Baruch et al. (2021, p.12) proposed a revised definition, defining PR as 'an ongoing process by which teachers develop and articulate theoretical and/or practical understanding to describe why, what, and how their practices lead to sustainable learning'. This definition emphasizes three aspects. First, through planning and enacting soundly reasoned classroom experiences and reflecting on them, teachers develop new understandings that add to their existing knowledge base (e.g., PCK) (Loughran, 2019). In other words, PR draws upon teachers' professional knowledge and adds to it. Second, when teachers make their reasoning explicit by articulating the *why* of their practice, they give insight into their professional knowledge. Since this knowledge is tacit, PR offers a way to unpack the unseen aspects of practice (Loughran, 2019). Lastly, with sustainable learning at its core, PR differs from other types of decision-making based on managerial aspects of classroom practice.

Technology-related Pedagogical Reasoning

Ideally, teachers' decisions to use technology are based on sound pedagogical reasoning, wherein they utilize their professional knowledge base (i.e., TPACK) to make informed technology-related classroom decisions (Forkosh-Baruch et al., 2021). Given this importance, scholars have recently begun exploring PR in the context of technology integration in two distinctive yet related strands. The first strand, the process strand, primarily focuses on adopting or revising Shulman's MPR&A to analyze teachers' adoption of PR processes when integrating technology (see Smart et al., 2016; Starkey, 2010). The second strand adopts a product-oriented focus, using PR as a lens to unpack teachers' technology-related wisdom of practice - knowledge cultivated through multiple cycles of PR&A (Shulman, 1987). Research in this strand predominantly tries to grasp the pedagogical rationales underlying teachers' technology adoption. As this is also the aim of our study, we further elaborate on this strand of research.

Teachers' Rationales Guiding Their Technology Integration

Research has discovered a wide array of rationales influencing teachers' decisions regarding technology integration. For instance, the study by Hughes et al. (2020), identified that teachers employed technology in a student-centric manner, emphasizing its value in (a) facilitating knowledge and skill development, (b) supporting visual needs, (c) tailoring learning toward needs, and (d) monitoring students' progress during assessments. Similarly, Heitink et al.'s (2017) study outlined the reasoning behind their technology use among primary school teachers. Emphasizing intentions to (a) make learning attractive for students, (b) achieve educational objectives, and (c) facilitate the learning process. Lastly, McCulloch et al. (2018) explored the technology-related decision-making of early-career secondary math teachers. They found that teachers' technology integration decisions are made based on (a) alignment with goals, (b) ease of use, (c) supporting instruction, and (d) access and compatibility.

METHODOLOGY

Although there is a growing body of research on TPR, further exploration is warranted to grasp this concept better. Moreover, research requires more discipline-specific reasoning studies (Hughes et al., 2020). Therefore, this qualitative interview study explored the TPR of secondary school math teachers, examining how they reason about using technology in their technology-mediated practices and ascertaining potential differences among math teachers' TPR. As such, the research questions of this study are:

- RQ1: What pedagogical reasons underpin the technology-mediated teaching practices of secondary school mathematics teachers?
- RQ 2: How does technology-related pedagogical reasoning differ among secondary school mathematics teachers?

Participants

A voluntary response sampling approach was adopted (Murairwa, 2015), involving a region-wide call for participation distributed to multiple secondary schools in Flanders. This call targeted math teachers who frequently use technology for teaching and learning, thereby ensuring that participating teachers' technology integration efforts are unimpeded by external or internal barriers, allowing for the investigation of teachers' TPR. To verify whether the participants met the desired sample criteria, teachers were asked to complete a questionnaire providing demographic information, the frequency of their usage of various tools, and the extent to which they encountered external barriers (e.g., ICT infrastructure, ICT policy). Seventeen Flemish secondary school math teachers were selected to participate. On average, participants have 15.9 years of teaching experience in math (SD = 9.6, min = 1, max = 37).

Data Collection

After collecting participants' informed consent, semi-structured interviews were conducted. During the interview, teachers were asked to describe their adoption of technology in their math classroom and their reasons for doing so. For each mentioned technology, teachers were prompted to detail (a) the classroom activities within which the technology is usually deployed, (b) the subject matter in which the technology is used, and (c) their reasons for using the technology. Each interview was audio recorded and transcribed verbatim.

Limitations

This study has several limitations. The small sample size and voluntary response sampling limit generalizability and may introduce self-selection bias (Murairwa, 2015). While insightful, the qualitative approach examines teachers' TPR profiles at a specific time, potentially missing TPR's changing, evolving nature throughout one's teaching career. Additionally, the study's regional context and focus on motives for technology use over motives for non-use further constrain the findings' applicability and comprehensiveness.

Data Analysis & Results

A qualitative content analysis was adopted to analyze the interview data, which is 'a research method used for the subjective interpretation of the content of text data through the systematic classification process of coding and identifying themes or patterns' (Hsieh & Shannon, 2005, p. 1278). The coding procedure consisted of several phases. First, we identified the technology-mediated practices of the teachers. On average, teachers described eight practices (Min = 4, Max = 12). For each practice, we labeled the tools mentioned by the teachers. These were then counted and grouped into categories based on the tool classification by McCulloch et al. (2018) (see Table 1). Teachers outlined a total of 130 technology-mediated learning activities employing various types of tools. The most frequently mentioned tools were GeoGebra (16 out of 17 teachers) and BookWidgets (15 out of 17 teachers). Notably, the utilization of tools varied not only between and within a teacher's practice, as many described different ways to deploy the same technology. For example, BookWidgets was adopted as an assessment tool, as an instructional software for practicing concepts, or as a LMS for organizing and sharing resources.

Table 1

Frequencies of types of technology tools mentioned by participants.

Type of technological tools	n	%	Technologies mentioned
1. Dynamic math environments (DME)	35	26,9	Geogebra, Desmos, Excel
2. Learning Management Systems (LMS)	23	17,7	Google Classroom, Smartschool, Microsoft Teams, Bookwidgets
3. Instructional software	19	14,6	Polpo, Diddit, Scoodle, Bookwidgets, Microsoft OneNote
4. Assessment tools	18	13,8	Kahoot!, BookWidgets, Socrative
5. Presentation tools	17	13,1	Digital textbooks, PowerPoint, Cloudwise, Interactive Whiteboards
6. Videos	13	10,0	YouTube, WeZooz, RecordYourself, Screencast
7. Calculation tools	3	2,3	Photomath
8. Collaboration tools	2	1,5	Google Docs

Teachers' Rationalizations Underpinning their Technology-Mediated Practices

Both deductive and inductive coding approaches were adopted to examine teachers' pedagogical reasons for adopting technology in their practice. A hierarchical coding framework was created based on Kolb's (2017) Triple E – Engage, Enhance, Extend – a framework to code deductively. This framework categorizes three main motives for teachers to integrate technology into teaching and learning: to *enhance* students' learning by supporting and scaffolding their understanding, to *engage* learners in the learning process, or to *extend* learning beyond the classroom. In addition, aligned with Kopcha et al.'s (2017) suggestion that teachers perceive technology use as effective when it facilitates smoother classroom management, we extend Kolb's Triple E framework with a fourth dimension: *Efficiency*. This expanded framework, encompassing 4E's, 'provides a robust framework for understanding a teachers' decision to use technology' (Kopcha et al., 2017, p. 740). Next, we defined literature-inspired sub-codes for each E. For example, the ICAP framework (Chi et al., 2018) guided the creation of the sub-codes *active*, *constructive*, and *interactive* within the main code of Engage. Likewise, the three main didactical functionalities of using technology in math (*computational efficiency*, *practicing skills*, *conceptual understanding*), as described by Drijvers et al. (2011), were used to code teachers' usage of technology to scaffold learning, which is a sub-code within Enhance. Aside from this deductive approach, sub-codes were inductively added and refined throughout the coding process. For example, *alleviating workload*, *classroom efficiency*, *construction efficiency*, and *tool efficiency* emerged as sub-codes for Efficiency, while *formative assessment* emerged as a sub-code for Enhance. The final codes and their descriptions can be found in Table 2.

Table 2

Summary of pedagogical reasons mentioned (n = 276), categorized by the 4E framework, including descriptions for each rationale and their absolute and relative frequencies.

PR category	Pedagogical rationale for using technology	n	%
Engage		**48**	**17,4**
Motivation	Motivating students by addressing their basic needs or by providing fun alternatives to traditional learning methods (e.g., competition)	19	6,9
Focus	Minimize distractions and help students to concentrate.	2	0,7
Active	Support students to apply previously taught knowledge	17	6,2
Constructive	Encourage students to acquire new knowledge independently.	8	2,9
Interactive	Allow students to acquire new knowledge collaboratively.	4	1,4
Enhance		**91**	**33**
Deeper learning	Foster higher-order thinking skills (analyze, evaluate, create)	22	8
Differentiation	Personalize learning experiences to meet individual student needs	15	5,4
Conceptual support	Supporting conceptual understanding via visualizations or by generating multiple examples.	19	6,9
Computational efficiency	Offloading computation to devices to reduce cognitive load	2	0,7
Practicing skills support	Supporting procedural and instrumental understanding via instant feedback, learning analytics…	16	5,8
Formative assessment	Gain insight into students' prior knowledge or current understanding to tailor instruction, share student work to offer feedback, etc.	17	6,2
Extend		**37**	**13,4**
24/7 learning	Offering opportunities for practicing and learning at home (e.g., remedial practice, flipped classroom)	26	9,4
Authenticity	Bridge classroom learning with real-world (examples, scenarios…)	5	1,8
Soft Skills	Developing students ICT-skills	6	2,2
Efficiency		**100**	**36,2**
Alleviating workload	Reduced time spent on grading, employing ready-made resources...	20	7,2
Construction efficiency	Quickly and accurately draw objects, graph functions, etc.	13	4,7
Classroom efficiency	Streamline classroom activities, quick resource sharing, efficiently guide students through online resources, monitor students easily…	48	17,4
Tool efficiency	Prevent the use of a plethora of tools by choosing a select few tools based on favorable aspects (seamless integration, multiple purposes)	19	6,9

A total of 276 pedagogical reasons were elicited by teachers when explaining their technology-mediated practices (Table 2). Overall, results indicate that teachers' decisions to use technology are most frequently underpinned by efficiency (36,2% of the analyzed reasons) or enhancement reasons (33,0%). To a lesser extent, teachers elicited engagement (17,4%) and extension (13,4%) reasons.

Differences among Math Teachers' Technology-Related Reasoning

To compare differences in TPR among math teachers, we created data displays (Miles et al., 2014) to present teachers' reasons for using technology in their math classrooms. The TPR data of each teacher were summarized into the 4E categories, facilitating comparative analysis and the identification of potential TPR profiles. As a result, three distinct profiles of math teachers were identified (see Table 3): Efficiency Navigators (*n* = 8), Learning Facilitators (*n* = 5), and Instructional Innovators (*n* = 4). Below, we elaborate on each profile, providing statement examples rendered in English.

Table 3

Average relative frequency (Mean (SD)) of each PR category per profile

	Enhance	Engage	Extend	Efficiency
Efficiency Navigators	15,6 (6,8)	12,7 (10,1)	17,4 (6,5)	54,3 (7,9)
Learning Facilitators	42,3 (8,7)	8,4 (2,8)	13,8 (4,3)	35,5 (9,6)
Instructional Innovators	41,6 (7,5)	27,6 (3,3)	16,3 (10,8)	14,5 (1,5)

Profile 1: Efficiency Navigators

Efficiency Navigators are math teachers who embrace technology primarily for *efficiency*, aiming to streamline and simplify their tasks and class activities. They prefer tools that are easily accessible, well-integrated with other tools, or provide additional structure to the course. They prefer using technology in the classroom rather than offering students hands-on activities. For example, they rely on presentation tools to guide student learning efficiently, use GeoGebra to demonstrate mathematical concepts, and utilize an LMS to organize learning materials neatly in one place. When materials are readily available, such as those created during COVID-19, these teachers may adopt extension and engagement rationales, valuing technology for providing students with fun alternatives for additional practice at home at their own pace. Concerning enhancement, they recognize technology's ability to scaffold learning, such as visualizing abstract concepts or providing instant feedback. However, they are less likely to embrace technology to facilitate deeper learning or differentiation practices.

> "Once I considered my approach to teaching a subject, I started thinking about various methods of delivery. I consider whether it can be handled by simply using paper and the whiteboard or whether I should use an online method. Ultimately, I opt for the most efficient method available. Whether that's traditional pen and paper or an online solution, either choice works for me." (Participant 5)

Profile 2: Learning Facilitators

Learning Facilitators are teachers who blend *efficiency* and *enhancement* motives when adopting technology, aiming to streamline learning activities while harnessing technology's potential to facilitate student learning. For instance, they value DMEs for quickly generating visualizations and supporting students' conceptual understanding. Unlike Efficiency Navigators, these teachers are more likely to engage students hands-on with technology, recognizing its value in providing immediate feedback, tailoring exercises to competency levels, and tracking students' progress easily. Similarly, Learning Facilitators view assessment tools not merely as a fun diversion in the classroom but as deliberate instruments for gaining insight into student learning to, subsequently, adjust teaching practices accordingly. Additionally, Learning Facilitators appreciate how calculation tools or DME can empower students to evaluate their work, thereby fostering their mathematical problem-solving and reasoning. Like Efficiency Navigators, these teachers extend learning beyond the classroom, but they do so with a more deliberate approach, carefully selecting instructional media that cater to students' individual learning needs. Lastly, Learning Facilitators' technology-mediated practices reflect a more traditional perspective on teaching and learning, with little emphasis on engaging students in (social forms of) knowledge construction of new knowledge.

> "It's useful for students mainly for differentiation. They can set their own pace when doing exercises. If it becomes too difficult, they can come to me. Otherwise, they can work independently online. (...) And also, it's useful for me. I can keep track of students' progress and I'm able to keep up with grading more easily." (Participant 3)

Profile 3: Instructional Innovators

Instructional Innovators prioritize *enhancement* and *engagement* motives when incorporating technology into their teaching practices, recognizing its potential to support student learning and enhance students' cognitive engagement and motivation. Unlike Learning Facilitators, they use technology to scaffold (social) constructivist classroom activities, supporting students to (collaboratively) acquire new knowledge. For instance, they will likely employ DMEs to facilitate students' active exploration and discovery of mathematical properties and concepts. Moreover, assessment tools in their hands serve various purposes, ranging from efficient grading, providing immediate feedback, and monitoring students' learning to offering an engaging alternative for reviewing concepts. Additionally, they recognize the value of using instructional software not solely from a teacher-centric perspective but also in empowering students, offering them insight into their learning progress, and fostering agency over their learning journey. Lastly, unlike the other profiles, Instructional Innovators take a more innovative and creative approach to technology adoption, seeing it as a catalyst for creativity, inquiry, and collaboration. For instance, they encourage students' peer feedback on each other's video-recorded mathematical reasoning, implement Flipped Classroom methods, and engage students in inquiry learning through WebQuests.

> "Implementing it not only streamlines the lesson but also provides additional visual support for the students (…).And, personally, I believe that I shouldn't be the sole conveyor of mathematical knowledge in my lesson, where I solve all the exercises on the board and continuously prompt students for answers, question after question. They should actively contribute to the lesson, and the use of this technology facilitates that." (Participant 1)

DISCUSSION/AREAS FOR FUTURE RESEARCH

This study aimed to investigate secondary school mathematics teachers' TPR, examining their rationale for integrating technology into teaching practices (RQ 1) and identifying variations in their TPR (RQ 2). The findings suggest that mathematics teachers primarily adopt technology for enhancement and efficiency. The prevalence of enhancement motives aligns with existing literature, indicating that teachers use technology to facilitate and augment student learning and skill acquisition (McCulloch et al., 2018; Heitink et al., 2018; Hughes et al., 2020). Regarding efficiency, our study reveals that mathematics teachers appreciate technologies that streamline their professional tasks, corroborating the view that technology is effective when it saves time or efficiently manages tasks (Kopcha et al., 2017). However, when considering the various efficiency rationales identified in this study, a question arises about the extent to which all these rationales can be classified as PR. In this context, Forkosh-Baruch et al. (2021) describe PR as reasoning with a core of sustainable learning. Given this description, there is a need for nuance within the Efficiency category, differentiating technology use motivated from either a (subordinate) pedagogical motive (e.g., freeing up time during instruction to be spent on additional practice and review) or a practical motive (e.g., reducing manual grading, convenience).

Concerning the second research question, three distinct profiles of TPR were observed among teachers: *Efficiency Navigators*, primarily driven by efficiency reasons in their technology use; *Learning Facilitators*, blending efficiency and enhancement rationales for their ICT adoption;

and *Instructional Innovators*, underpinning their technology use based predominantly on enhancement and engagement motives. The authors of this paper hypothesize that differences between profiles could be attributed to differences among (1) teachers' professional knowledge base or (2) their pedagogical beliefs. Regarding the first hypothesis, the findings reveal a contrast among profiles regarding their years of experience in teaching math. On average, 11,4 years for Efficiency Navigators, 18,0 years for Learning Facilitators, and 22,8 years for Instructional Innovators. As teachers' professional knowledge base grows over years of teaching, cultivated through various cycles of PR&A (Shulman, 1987), it is reasonable to infer that teachers within the second and third profiles possess a more comprehensive knowledge base. This could allow them to discern technologies' potential more adeptly in enhancing students' learning experiences or fostering students' engagement. As for the second hypothesis, it could be posited that teachers in the third profile hold stronger student-centered pedagogical beliefs, thus leveraging technology in facilitating more student-centered pedagogies (Li et al., 2019), potentially explaining the more prevalent engagement rationales observed in this profile.

This study indicates that teachers can differ significantly in their reasons for adopting technology. However, this study's exploratory, small-scale nature highlights the need for future research. For instance, future research could focus on developing a TPR questionnaire and using cluster analysis on a larger dataset to corroborate our TPR profiles or identify new ones. The 4Es framework used in this study could serve as a basis for this questionnaire. Next, exploring teachers' reasons for rather than against incorporating technology may offer only a partial understanding of teachers' TPR. To gain a more comprehensive insight into TPR, it may be essential to investigate why certain teachers abstain from using specific technologies. For example, there are instances where technologies distract rather than engage learners or diminish rather than enhance learning experiences. Insights from such studies, combined with the findings from this study, could offer valuable insights to practitioners involved in the professional development of teachers in technology integration or in preparing student-teachers for technology integration.

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