Instructors' Acceptance of a Questioning Classifier Tool for Elementary Mathematics Teacher Education

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Abstract: In mathematics teacher education, a focus on equitable mathematics teaching has increased efforts to support preservice teachers (PTs) toward promoting mathematical discourse in their future classrooms. The goal of this study is to determine if instructors of PTs would accept a mathematical discourse technology, the questioning classifier tool (QCT), to implement in their elementary mathematics methods courses. Qualitative methods included conducting interviews with three instructors and coding the interview transcripts using the technology acceptance model. Findings include the instructors' perceived usefulness of the QCT's data for themselves and for their PTs, changes they would suggest to improve their perceptions of the QCT's usefulness and ease-of-use, and ways to immediately incorporate the QCT into their course as well as their intention to do so. Implications include ways to modify the QCT, and similar tools, to support instructors of elementary mathematics methods courses to integrate classifier tools into their courses to support PTs in mathematical discourse.

Keywords: preservice education, mathematical discourse, questioning, AI-based tools

Introduction

In mathematics teacher education contexts, a focus on equitable mathematics teaching has increased efforts to support preservice teachers (PTs) to develop their ability to promote mathematical discourse in their future classrooms (e.g., Chapin et al., 2009; Liljedahl, 2020; Smith & Smith, 2022). To develop a high-impact teaching practice such as mathematical discourse, PTs need intentional and focused practice (e.g., McGarr, 2021) through substantial rehearsal opportunities (Grossman et al., 2009) in which they practice mathematical questioning. Further, the PTs need to receive high-quality feedback on their mathematical questioning that they can then act upon (Pianta & Hamre, 2009). Unfortunately, mathematical discourse opportunities are often limited for teacher education programs (Forzani, 2014) as most technology tools to provide simulated rehearsal opportunities (e.g., Cohen et al., 2020; Mikeska et al., 2022) are expensive and logistically challenging (e.g., Dalinger et al., 2020).

As part of a larger project, the AI-Based Classroom Teaching Simulator (ACTS) for Teacher Education (Bywater et al., 2024), this paper considers the use of a questioning classifier tool (QCT) in the context of elementary mathematics teacher education. This QCT is an artificial intelligence (AI)-based webpage with the ability to classify question types according to different categories. Instead of the cost and logistical challenges of many simulated environments, we anticipate that this QCT could be more readily accessible and usable by instructors hoping to implement technology to support their PTs' mathematical discourse. Specifically, in this study,

we consider how the instructors of PTs report upon the potential usefulness and ease-of-use of the QCT for implementation in their own elementary mathematics methods courses.

The goal of this study is to determine if the instructors would accept the QCT to implement in their course as well as what changes they would suggest to improve their perceptions of the QCT's usefulness and ease-of-use. We then address the following research question: What are elementary mathematics methods course instructors' perceptions of the usefulness and ease-of-use of the QCT and its potential implementation in their courses?

Framework

To determine instructors' acceptance of, or intentions to implement, the QCT in their courses, we utilize the technology acceptance model (TAM) for perceived *usefulness* and *ease-of-use* (Davis et al., 1989). This framework has been utilized within teacher preparation research for mathematics education to determine PTs' acceptance of, or intention to use, different technologies in their future classrooms (e.g., Casey et al., 2023; Daher et al., 2017; Joo et al., 2018; Wong, 2015; Yeo et al., 2022). This study expands the framework to consider instructors' acceptance, or intention to use, a technology within their courses. Specifically, we focus on determining instructors' acceptance to use the QCT within their elementary mathematics methods courses to support PTs to engage in mathematical discourse. We utilize the TAM framework's two key constructs: *usefulness* as the extent to which someone believes that using the technology would improve their performance, and *ease-of-use* as the level of effort someone believes that they would have to put forth to use a technology (Davis et al., 1989).

Literature Review

The National Council of Teachers of Mathematics (NCTM) defines mathematical discourse as the "purposeful exchange of ideas through classroom discussion, as well as through other forms of verbal, visual, and written communication" (NCTM, 2014, p. 29) and promotes mathematical discourse throughout their essential teaching practices (NCTM, 2014). In the field of teacher education, supporting PTs to both develop skills with facilitating mathematical discourse and plan to integrate mathematical discourse within their future classrooms is important to enable PTs to promote inclusive conversations about mathematical ideas (Olawoyin et al., 2023). When all students are supported to engage in these inclusive conversations, their access to mathematics learning is more equitable (Lilly et al., 2023; Oakes et al., 2001), and teachers are able to support students to develop deep understandings of mathematical ideas (Ball, 1993) and their own mathematical identities (Aguirre et al., 2013). However, elementary PTs rarely have the opportunity within their teacher preparation programs to practice engaging students in mathematical discourse.

Prior research has then considered how to utilize technology to support PTs with simulated rehearsal opportunities through which to develop their skills in mathematical discourse. This includes AI-based tools that simulate teacher-student interactions between two or more participants in face-to-face scenarios in mathematics methods courses (Shaughnessy & Boerst, 2018), mixed-reality virtual environments in which PTs interact with virtual students that are controlled by humans (e.g., Cohen et al., 2020; Dalinger et al., 2020), and web-based systems in which PTs communicate with AI-based virtual students about mathematical tasks via a chat interface (e.g., Bywater et al., 2024; Chiu et al., 2022). Each of these systems, however, may require more facilitation from the instructor, resources to pay for access to the system, and, in some cases, only one preservice teacher can engage with the technology at a time. Both the face-to-face and human controlled environments also lack the ability to give automatic feedback to either the instructor or the preservice teacher, and this tailored feedback is crucial to PTs' growth with mathematical discourse (Chernikova et al., 2020).

The types of questions that systems can give feedback on should also be considered. Prior research in mathematics teacher questioning has shown the importance of asking purposeful questions that elicit as well as explore student thinking (NCTM, 2014). Instead of limiting mathematical discourse by focusing on procedural or factual accuracy, including questions about algorithmic processes or basic mathematical operations, teachers should include questions that explicitly discuss student thinking (NCTM, 2014). These types of questions include encouraging students to clarify their thinking, compare and contrast alternative approaches, and justify their processes. Prior frameworks of mathematics teacher questioning include describing questions and their role in

mathematical discourse (Boaler & Brodie, 2004), questions classified based on how they press students to describe their conceptual understanding (Kazemi & Stipek, 2009), questions that center students' reasoning and ideas through funneling (Wood, 1998), and ways to measure teacher questioning based on the degree of probing or exploration questions that the teacher uses (Boston & Candela, 2018).

The QCT in this study, discussed more below, (1) pulls upon these research-based questioning classifications, (2) can be used with many PTs at the same time to help them practice how to ask a variety of questions types when supporting students through a mathematics task, and (3) gives immediate feedback to each preservice teacher on the question types following each question.

Methods

In this study, we use qualitative methods to examine the perceptions of elementary mathematics methods course instructors in regard to the QCT and its potential usefulness and ease-of-use within their course.

Questioning Classifier Tool

As part of the larger ACTS project for elementary mathematics methods courses, we created the QCT to be accessible to instructors via a web page and to classify teacher questions according to different categories: probing or exploring, high/low press, funneling/focusing, and assessing/advancing (Fig. 1). The instructors were informed that the QCT could be retrained to classify different types of questions depending on their course's needs, and they were able to practice with the QCT prior to their interview to see immediate feedback on the question types.

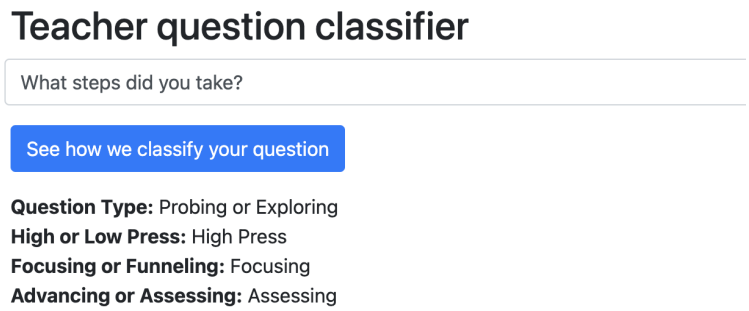

Figure 1. Example Question Classification from the QCT

Participants

Three elementary mathematics methods instructors at the same large mid-Atlantic university were contacted via email, following their participation in the larger simulator project, to gauge their interest in discussing the QCT with the researchers. These instructors (Kiefer, Linda, and Grace, pseudonyms) all had prior elementary teaching experience and have been course instructors for the elementary mathematics methods at the university for several years prior to this study (Kiefer: 5 years; Linda: 20 years; Grace: 3 years). The instructors were not compensated for their time with the QCT, but they have access to the QCT and are supported in co-designing the tool with the researchers to fit the needs of their course and their PTs for following semesters.

Data Sources and Collection

After having one week to review and practice with the QCT, each instructor was individually interviewed via Zoom by one of the researchers. Each interview was at least 30 minutes long, followed a semi-structured interview protocol with open-ended questions (Miles et al., 2020), and was audio recorded. The interview protocol included questions about the instructors' initial perceptions of the QCT, how the QCT could be used for elementary mathematics teacher preparation, and their goals in implementing the QCT and supporting their PTs to engage with the QCT. The questions were also structured to explore how the instructors might consider integrating the QCT to fit within their course plans, utilize the QCT, and plan for PTs' interactions with the QCT. The audio recordings of each interview were then transcribed and blinded.

Data Analysis

After two researchers separately read each transcript, they discussed their initial takeaways and decided together to use a provisional coding approach by applying a priori codes from the TAM framework to the data (Miles et al., 2020, p. 69). After reviewing the framework together, the two researchers engaged in team coding (Miles et al., 2020) to assign codes to each transcript statement. This enabled the researchers to share their thoughts on each statement as they discussed and reached agreement on any uncertainties in their codes. The researchers then developed summaries for each participant as well as looked across the instructors' coded statements for patterns and wrote analytic memos that became the basis for the findings below (Miles et al., 2020).

Results

We provide a brief summary for each participant followed by salient themes for *usefulness* and *ease-of-use* across instructors along with instructor quotes to support specific themes.

Kiefer

Kiefer thought that the QCT would be most useful as a tool for planning lessons with the PTs. He believed this would help them understand more about the different types of questions, recognize the purpose of each type of question, and think more intentionally about the conversations they are planning to have with students. Since there are several lesson planning assignments throughout the semester, Kiefer thought that there would be many opportunities within his methods courses to use the QCT in-class. Kiefer thought that the QCT was easy to use and accessible, and that in-class activities with students using it in pairs would aid thoughtful conversations about questioning. Kiefer also suggested that the QCT could be useful for all teachers, including in-service teachers, and suggested two design changes that would improve it: have the QCT focus on one type of classification and retain prior queries on the page.

Linda

Linda also saw the role of the QCT as a support for lesson planning and developing an understanding of when to use different types of questions. The students in Linda's methods course develop a lesson plan that they will teach as part of their practicum experience. Linda saw the QCT as helpful for ensuring that students included different types of questions in their plans. For Linda, there was a clear need to support students to learn more about questioning, as this is currently a goal in their methods course, and so she believed the QCT would be a valuable addition. Linda anticipated using the QCT in-class and asking students to use it individually. While the course would focus on questioning over several sessions, Linda anticipated that the QCT could be a straightforward activity that would take about 20 minutes. Because Linda considered the QCT to be easy to use and implement, she felt that no explanation

for how to use it would be necessary. She said she would have no hesitations using it in class despite also commenting that she does not typically use technology in her course.

Grace

Grace thought that the QCT would be useful, because her PTs would value the specific feedback as they are open to growing their teaching skills. Grace prepares special education teachers who are adult learners currently working in K-12 schools. She recognized that differences between teacher-student conversations across grade levels would need to be considered.

Grace saw a role for the QCT throughout their coursework, because she viewed supporting discourse and questioning as an oncoming concept transferable across different grades and content areas. For Grace, implementing the QCT initially would be done with modeling and scaffolding, allowing more time initially (about one hour), perhaps with PTs working in groups, and less time (about 20 minutes) at subsequent occasions, perhaps with PTs working in pairs. This would help PTs become familiar with the tool and with the feedback it provides. Grace reported her belief that the longer initial use would ensure that an instructor could model how to use the QCT but also emphasize the intended use, goals, and how to reflect on the feedback from the QCT. She also commented that it might be valuable to extend the QCT to report on if PTs are providing positive reinforcement given its importance in special education.

Usefulness

Themes across the instructors for *usefulness* included: the availability of questioning data to instructors and PTs; instructors' desire to use data to inform their instructional decisions and support PTs to inform their instructional strategies; the support the QCT offers to focus on types of questions; the option to create different partnering across multiple iterations; an ability to incorporate other skills into their mathematics methods course; the adaptability of the QCT to their specific course context to fit their curriculum and the needs of their PTs; and the access to practicing asking questions in mathematics contexts that the QCT can provide.

In this paper, we focus on the themes of data availability and using data to inform instructional decisions and strategies. Each of the instructors discussed the importance of their PTs having immediate feedback from the QCT. For example, Grace discussed how instructors can explain to their PTs the importance of discourse and using questioning within their discourse. Further, PTs may feel that they are using different levels of questioning. For Grace, the usefulness of the QCT is its ability to quantify the questions immediately. For example, Grace said, "Just giving it the label of what it was versus what we perceive ourselves to have done. It gives them actual hard data … you may feel like you're asking questions. But really, how many did you ask?" Similarly, Kiefer discussed how he was eager to view the PTs' results to help them understand if their questioning aligned with their expectations and to learn, himself, about the variety of question types being asked. He believed that the activity could bring to his PTs' attention ways that they need to change their questioning but could also help build their self-efficacy in mathematical discourse. For example, he said:

> I hope they'll think: 'Wow, I am capable of doing this.' Sometimes people who are going to be really good teachers get going, a lot of their instincts kick in, and they do the right things out of instinct. I hope they can say, 'Oh, I actually am doing well with this. Here's documentation of it.'

He also stated the need for all the question categorizations to be shown together upon completion of an activity. Linda was also interested in the results, saying "I wonder, over time, after having looked at the kinds of questions the first time, how did they do the second time? I'm really looking forward to seeing what the data shows there." These quotes show the instructors' interests in both supporting the PTs to understand the QCT's data and analyzing the data themselves.

The instructors also each discussed how the data could inform their instructional decisions within the course as well as their PTs' decisions about how to use questioning with mathematical tasks. Kiefer specifically spoke about supporting his PTs to find a balance between questioning types. For example, he said, "Then I would need to go back and revisit. Let's talk about questions that can move students thinking forward because all you're doing is asking questions that are looking for answers and not understanding." Grace also discussed how just the

thought of having the QCT to use in her course was changing her instructional decisions about how to structure the semester. She said, "To be honest, I wouldn't say we typically have a focus on discourse throughout. We discuss it and then leave it. But this tool prompted me to remember … [questioning] is something that has to be consistent throughout content." These quotes show how the instructors are already anticipating utilizing the QCT data within their course and supporting their PTs to also utilize the data.

Ease-of-Use

Themes across instructors for *ease-of-use* included that the ease-of-use of the QCT would: make all of the above *usefulness* aspects possible; enable the instructors to pair the QCT with their existing curriculum; prepare the PTs for their practicum settings; enable the instructors to scaffold the PTs' interaction with the QCT; contribute to their comfort in implementing the QCT with little training and their PTs' comfort in engaging with the QCT; and correspond to a variety of possible mathematical tasks as a unique tool to prepare PTs for the classroom. In considering *ease-of-use*, themes across instructors also included their suggested changes to the QCT and potential technological challenges in implementing the QCT in their courses.

In this paper, we focus on the themes of the QCT corresponding to a variety of possible mathematical tasks to prepare PTs for the classroom as well as the instructors' comfort in implementing the QCT. First, each of the instructors was able to readily propose possible ways to integrate the QCT into their course. Specifically, all three instructors suggested using the QCT with lesson planning activities. Linda suggested having PTs apply the QCT to their already written lesson plans and then revising their lesson plans based on their results. She felt that this fit with the way that she already presented mathematical questioning content in her course and also would give her PTs more feedback that they could use immediately to revise their lessons. She said, "They can see what they were asking. I just can't get through the lesson plans fast enough to have them revise on that level, looking at every question. That would be awesome." Kiefer and Grace, meanwhile, thought about having their PTs use the QCT through the process of drafting a lesson plan. Kiefer said, "They can see if they're only asking questions one way, if they have a variety. It will just help them make sense of what they're asking." In each case, the instructors felt it was important that the PTs have the opportunity to engage with the QCT before submitting their lesson plans which created an additional feedback opportunity other than what the instructors alone could offer.

All three instructors were also able to suggest specific mathematical tasks that they would give their PTs to use with the QCT. Although the mathematical content of their tasks were different, both Linda and Grace discussed having their PTs write out different questions types that they would use to introduce the problem to their future students and categorize these questions with the QCT. Kiefer suggested having his PTs work through a mathematical task first themselves and then, after they had a solution, map out the questions that they would ask students. He said, "I would ask if they think students will largely solve the problem in this fashion? What kind of questions would they start using? Let them see, 'I am strong in this category but weak in this one.'" He also suggested an activity in which PTs are given a list of questions, pick ones to build different lines of questioning, and then consider what might happen with each line. After trying each line of questioning with a partner, the PTs could then categorize the types of questions themselves and check their thinking with the QCT. These different activity examples show that the instructors were able to consider multiple ways to integrate the QCT into their current course plans.

Yet, the instructors also made clear that they did not typically use tools like the QCT in their course. For example, Grace described how, before her PTs could practice independently with mathematical tasks at different K-12 levels, she would first give specific directions and model the QCT. She felt that this was important because, "This is not something that is typically available in preservice teaching curriculum. They won't have seen it before." Linda and Kiefer both stated that their courses are more "old-fashioned" and typically do not involve much technology. For example, Kiefer said, "This would be a change. But I could see my students thriving, because they like to be on their devices and like that kind of instant feedback that they wouldn't get otherwise." These quotes show how the instructors felt that the QCT would be a unique tool in preparing their PTs for classroom settings.

Despite saying that the QCT would be a novel tool in their classroom, each instructor said that they would be able to implement the QCT. For example, Linda said, "It's just pretty straightforward. You type a question in, and it tells you what kind it is. I could implement it as soon as I wanted to." Kiefer said, "I feel like it was pretty user friendly and direct and accessible. I have a pretty good handle on it." When asked if she had any hesitancy in

implementing the QCT, Grace simply replied, "No." These quotes show that the instructors perceive the QCT as easy for them to implement within their courses.

Discussion and Implications

This study considers instructors' acceptance of a questioning classifier tool to support the use of information technology in the context of questioning for mathematics education. Findings show that instructors perceive that the QCT would be useful for their course and easy to use for both instructors and PTs. Additionally, and in line with prior research, the instructors recognized the importance of having the QCT for their course in order to support their PTs to engage in mathematical discourse practices (e.g., Chapin et al., 2009; Liljedahl, 2020; Smith & Smith, 2022) with immediate and actionable feedback (Pianta & Hamre, 2009). Specifically, when considering the types of activities that they would implement with the QCT, the instructors indicated that the QCT could give immediate, actionable feedback to each PT in a way that the instructors could not. Each instructor also indicated that they would accept this model by noting ways that the QCT could be important to their course and indicating that they would like to try to implement it in their courses to support the work that they are already doing to engage PTs in mathematical questioning.

As the instructors explained how they were considering integrating the QCT to fit within their course plans, utilizing the QCT, and planning for PTs' interactions with the QCT, there were several implications for how the researchers can support the instructors. First, although the instructors perceive themselves as readily able to implement the QCT, the researchers can co-design the QCT with the instructors to support technology and content integration by fitting the QCT to the questioning types that each instructor regularly teaches. This includes, as Kiefer suggested, beginning with one questioning type on the QCT and then introducing more types to PTs as the semester continues. Similarly, the researchers can also program the QCT to include a final summary of all questions and types at the end of an activity.

Additional implications of this work include the potential use of the QCT for in-service professional development, changes to the QCT such as supporting PTs to understand how they could rephrase a question to change its classification, the importance of meeting PTs were they are in their understanding of mathematical questioning, supporting a variety of question types so that PTs are able to purposefully plan how they hope to engage students in mathematical discourse, and supporting instructors in how they hope to prepare PTs to engage in mathematical questioning in their future classrooms. This work is important towards understanding elementary mathematics methods course instructors' perceptions of the usefulness and ease-of-use of the QCT and its potential implementation in their course as well as considering their suggestions for ways to modify the QCT, and similar tools, to then help instructors of elementary mathematics methods courses to integrate questioning classifier tools into their courses to support PTs in mathematical discourse.

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