The Purpose of Teacher Questioning in Mathematics Classrooms

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Abstract

This research examines the research on the purpose of teacher questioning in mathematics classrooms. Questions are presumed to be an integral part of the learning process; this research attempts to understand the various purposes of said questioning in mathematics classrooms. Through a literature review of 30 peer-reviewed articles, 3 themes arose: teacher questioning for the purpose of 1) student learning, 2) formative assessment, and 3) classroom management. These themes are again discussed within an action plan where comparisons and suggestions are made to a local site. Finally, I will discuss what I found within the literature relative to my focal questions and finish with implications research has on best practices regarding teacher questioning in mathematics classrooms.

Keywords: teacher questioning, questions, mathematics classrooms, mathematics

The Purpose of Teacher Questioning in Mathematics Classrooms

Questions are defined as "an interrogative expression often used to test knowledge" (Merriam-Webster, 2024). Within classrooms, questions are used in exactly this fashion, as a means of testing what students see and hear. Contemporary learning models go as far as to prioritize question asking as a means of driving learning. However, it is important to remember that while students may ask questions to learn more about a subject, teachers also ask their students questions. A question that arose piqued my interest. Why do teachers ask their students questions? Essentially, what function do teacher questions serve for students in classroom settings? For me, as I transitioned from being a long-time student to newly certified teacher, it is not enough to simply presume that questions are an integral part of the classroom; I want to understand what purposes they serve to best support the learning of my students. This paper is an exploration of research on the purpose of teacher questioning (TQ) in mathematics classrooms.

Context

Within my school locally, I've noticed that students have slowly begun asking fewer questions in comparison to what I remember and expect of my time in middle school 10 years ago. In both of my recent experiences, student-teaching and being a full-time teacher in the secondary mathematics section, only a few students per classroom ask questions. This creates teacher-dominated lesson structures akin to banking. The teacher spends most of the time talking rather than responding and facilitating student curiosity. By understanding TQ, I hope that I can increase student voice within the classroom and model the different types of questions students might ask to better understand the subject at hand.

Regionally, us teachers in Washington state are also aligned in this goal. OSPI has increased the focus on developing critical thinking skills such as mathematical justification, creativity, application, and conceptual understanding (*Common Core State Standards for Mathematics*, n.d.). Thus, TQ may serve a purpose in creating opportunities for students to exercise and develop these various critical thinking and communication skills. These contemporary focal goals have produced learning models such as inquiry, problem-based learning, and project-based learning that are widely used at the national level. Shared within these learning models is again the idea of questioning as a driver of learning.

Importance

As a student and teacher, I strongly believe in the learning philosophy of constructivism, the idea that we are all individually constructing our understanding of the subject at hand. Similarly, as a child, I constantly used questions to learn about the world around me. They helped me understand subjects at a deeper level, or they allowed me to challenge ideas that I held previously. I believe that my students see questions similarly. Now, as a teacher, my interests have shifted from questioning the world itself towards questioning how those same questions, Teacher Questioning, can help my students understand mathematical subjects at a deeper level. Ultimately, this research came about as an attempt to understand how teacher questioning supports learning within the classroom.

To put aside, teacher questioning for a second, I believe that the idea of asking questions within communities and as learners is both simple and deep. Questions asked socially are used to generate conversation and understanding between people. Questions and the conversations that follow give insight into the lives of others and why they live the way they do. It is an integral part of our human experience within communities. Thus, understanding how teacher questioning can generate this conversation and understanding is similarly important to me.

Purpose

The purpose of this project is to improve my understanding of why and how to ask my mathematics students questions. By understanding the purpose of questions asked within mathematics classrooms, my goal is to understand how to ask different types of questions that help support the learning of mathematics. In this understanding, I believe that asking good questions will create thought-provoking moments and opportunities to evolve what they know.

Focal Questions

My research is centered around three focal questions:

- When analyzing mathematics teacher questioning generally, in what ways are practice and theory aligned or misaligned?
- What does research find to be important considerations for mathematics teachers when asking questions?
- According to the research, how does asking open-ended questions affect the learning of students within mathematics classrooms?

Literature Review

I examined the research on the Purpose of Teacher Questioning (TQ) in mathematics classrooms. Questions are generally assumed to be an integral part of the learning process. In mathematics classrooms, they're often used to introduce, test, challenge, and support students in their understanding of the subject matter presented. Questions exist everywhere within this span of a student's introduction and mastery of a subject. To list a few forms they may take: they exist as worksheets given to practice procedural applications, questions the students have for each other, and oral questions asked by the teachers. For teachers, understanding how to ask and apply questions within mathematics classrooms is key to engaging and challenging the learning of students in the classroom. The deliberate application of questions by the teacher orally, also known as Teacher Questioning (TQ), will be the focus of this literature review. The articles were not limited to only the United States; they covered the teaching of multiple countries such as Turkey, Japan, Germany, and the United States. The articles also spanned both qualitative and quantitative studies, in which the observation of this teacher questioning was analyzed from various metrics. Within the reading, three themes arose when pursuing the purpose of TQ in mathematics classrooms. These themes are teacher questioning for the purpose of 1) student learning, 2) assessment, and 3) classroom management.

TQ for the Purpose of Student Learning

In this section, I will examine and synthesize the literature on TQ for the purpose of student learning. An abundance of articles assert that TQ has positive effects on student learning. This *student learning* is defined in many ways. Those of modern importance include the progression and development of problem-solving, critical thinking, mathematical creativity, literacy, and the understanding and application of concepts (Aziza, 2018, 2021; *Common Core State Standards for Mathematics*, n.d.; DeJarnette et al., 2020; Hsu et al., 2023; Mahmud et al., 2021; Roberts, 2020; Yilmaz & Cakiroglu, 2024). Most of these student learning categories, such as critical thinking and application, are stressed as important learning goals in the Common Core Standards for Mathematics (*Learning Standards & Instructional Materials*, n.d.). Thus, they are a metric of importance for teachers who desire to use best practices within their teaching, and I will define student learning as such. Within this section, I will discuss various types of questions related to student learning and what research has to say about the effect TQ has on student learning.

When categorizing different types of questions asked within mathematics classrooms, various metrics were utilized to assess student learning. However, importantly, there were no strict quantitative metrics present within this research. One might expect there to be quantitative metrics measuring grades or student satisfaction before and after TQ interventions, but no metrics that directly measured student learning were present in the research studied. Most common were metrics that quantitatively measured the number of questions asked or qualitative observations recording teacher questions and student responses.

The two metrics most commonly used to assess student learning were Bloom's Taxonomy and Webb's Depth of Knowledge. These metrics are an attempt to understand and classify the scope of educational goals and objectives present in student learning (Bloom, 1956; Webb, 2002). Bloom's Taxonomy dives into these classifications of student learning, using qualitative categories such as *remembering* and *creating* that distinguish learning by levels of complexity (1956). Similarly, Webb's Depth of Knowledge (DOK) (2002) also classifies student learning by complexity. In Webb's DOK, *recall* and *reproduction* are labeled as low-orders of thinking, and extended thinking such as *application of concepts,* is labeled as higher-orders of thinking. These metrics for student learning interlaced created the consideration of higher-order thinking and lower-order thinking as measures of student learning effectiveness. Thus, researchers defining questions as higher-order questions or lower-order questions emerged.

In a mixed methods study of literature review and observational study, Simpson et al. (2014) do this work of interlacing Bloom's Taxonomy and Webb's DOK as shown in Table 1. They argue that using either Bloom's Taxonomy or Webb's DOK by themselves does not do an adequate job of capturing the level of thinking that students exercise during TQ (Simpson et al., 2014). While their study did not have a quantitative metric for the effects of this work on student learning, in comparison, no other studies in the research were as thorough in defining the differences between lower-order thinking and higher-order thinking. Thus, they serve as the guideline for higher-order and lower-order thinking regarding questions in the mathematics classrooms.

One example of a higher-order question and its responses occurred in a case study by Aziza (2021). During their observation of a year seven UK-based teacher, the teacher asks, “Who can tell me, why do these numbers always work?” (p. 47). By Simpson’s definition of a higher-order question, it qualifies as one because it asks students to explain reasoning processes that have not been revealed (Simpson et al., 2014). One student's response from Aziza (2018) demonstrates these higher-order thinking patterns. The student in response claims, “There is a difference of 3 in between them” (p. 47). Both this response and another response recorded in the study communicate the child’s analysis and conceptions of the subject in a way that is not simply yes or no; both responses were complete sentences requiring the student to recognize and communicate patterns, a higher-order of thinking according to Bloom (1956).

An example of a lower-order question occurs in a different study by Aziza (2018). In this study, a teacher being observed asked, “Can you tell me what $8 \cdot 4$ is” (p. 477). The obvious student response is simply, “32.” Objectively, a question like this asks students to remember or recall a fact, thus leading to its categorization as a lower-order question (Bloom, 1956; Simpson et al., 2014). Both higher-order and lower-order questions are said to affect student learning in different ways. I will begin discussing these differences by considering higher-order questioning first, then transition to lower-order questioning.

As mentioned previously, higher-order questions are those that utilize critical thinking skills present in Bloom's Taxonomy or Webb's Depth of Knowledge. Because they utilize these critical thinking skills, several authors recommend that teachers ask more higher-order questions (Aziza, 2021; Yildizli & Günaydin, 2022). Yildizli & Günaydin (2022) argue for this claim in their study. Through the use of a survey conducted on 265 elementary mathematics teachers in Turkey and a case study of two of those teachers, they investigate the different types of questions teachers ask and the aims of TQ. In this survey, they lay out different in-class questioning types and ask teachers to rate their use of these questions on a scale of 1-5. These categories range widely from gathering information, probing thinking, and encouraging reflection, as a few examples. When analyzing the categories for encouraging reflection/justification and making mathematics visible, teachers rated them at an average of 3.75 and 3.71, respectively, for how important they were on a scale out of 5. This aligns with higher-order questions that ask students to reflect; drawing connections becomes an iterative process for them. These types of questions, being higher-order in nature, ranked as the 3rd and 4th most important types of question type asked by teachers out of 10 categories. Though the survey list was limited, there is evidence to imply that teachers believe asking higher-order questions allows and supports student reflection and understanding of mathematics holistically. More specifically, teachers believe that asking higher-order questions requires the students *themselves* to explore the phenomenon in question with the critical thinking that teachers desire.

An important point of consideration that arose when discussing critical thinking is the students' personal ability to exercise these critical thinking skills themselves. DeJarnette (2020) mentioned that higher-order questions grant students *agency* in their learning; the questions themselves allow them the mobility to navigate learning on their own. While DeJarnette did not provide evidence for the statement, other articles are largely in agreement with her. In Roberts' (2020) case study centered around English learners, he implies that rich and high-quality discourse centered around mathematics helps engage English learners in their class and community. Higher-order questions create this high-quality discourse, which in effect grants students the agency to exercise their critical thinking and learning.

In Roberts' (2020) study of English Learner (EL) students, she found that it is not enough to simply ask questions that require higher cognitive demand; teachers must model what discourse and responses look like. When the teacher observed in Roberts' study began practicing this modeling, she found that she could hold her EL students to higher expectations rather than fixating on only asking procedural questions (Roberts, 2020). While they did not provide evidence of this modeling, there are examples in which the type of question asked directly implies the form of the response, such as when one of the teachers asks, "Someone told me it's now 11.5. Why do you agree or why do you disagree? What's going on?" (p. 145). This question was labeled as one that encourages reflection, but more importantly, it models exactly how a student might respond to this higher-order question. In this case, changing the way a higher-order question was asked helps to facilitate the discourse and learning present in the classroom.

However, it is important to note that while there was found to be a correlation between higher-order questions, quality of student response, and general quality of discourse, this was not always the case (DeJarnette et al., 2020; Roberts, 2020). For example, in a case study of two eighth-grade teachers in Tennessee, one specific conversation recorded comes to mind (McCarthy et al., 2016). In this instance, a teacher asks the student, "Where are the x-intercepts for this? So, in other words, if I set this equation to zero…" In reply, the student answered, "It's in the book." In some ways, this is an acceptable response, and in others, it diverts the purpose of the question. This type of response is not uncommon; it resolves the question at hand with low-orders of thinking, even though the question was one of higher-order thinking. This signals teachers that more work needs to be done than simply asking higher-order questions, if we as teachers want students to learn and engage in the thinking.

It is simply not always the case that asking higher-order questions produces higher-order discourse and learning. In fact, higher-order questions were even found to stall conversations in some cases (DeJarnette et al., 2020). Dillon (1983) agrees with this in his study of *Teaching and the Art of Questioning*. Rather than produce learning, it can forestall it. In my reading, I found two reasons for this. First, with the students in Roberts' (2022) case study, again, it can entirely be the case that students simply do not know how to respond to higher-order questions. In the case with EL students, there is a need to not only understand the context of a higher-order question but also to craft a response requiring more depth. Secondly, and more concerning for teachers, higher-order questions by definition consume more class time (Hsu et al., 2023). This is evident in both longer responses, longer required wait times for high-quality responses, and the nature of a higher-cognitive discussion (Aziza, 2018; Hsu et al., 2023; Roberts, 2020). Commonly, in the case studies read, it was found that teachers did not give enough wait time required to answer a question requiring higher-order thinking (Aizikovitsh-Udi & Star, 2011; DeJarnette et al., 2020; Roberts, 2020; Yildizli & Günaydin, 2022). Though anecdotal evidence, a general statement made in Hsu's case study, vocalizes this concern, "If we let students freely explore mathematics, it will take much of the class time and influence students' learning progression…" (Hsu et al., 2023, p. 1488). Teachers are concerned with student learning progression in a timely manner. Thus, teachers recommend that TQ encompasses a multitude of different types of questioning to balance both the depth of student learning and the timely progression of it (DeJarnette et al., 2020; Hsu et al., 2023; Tarasenkova et al., 2023).

Maybe unsurprisingly, lower-order questions are suggested to lay the foundation for higher-order questions (Di Teodoro et al., 2011; Koizumi, 2013). When analyzing the differences between two German and two Japanese mathematics classrooms, Koizumi (2013) found that lower-order questions were especially important in the introduction of content, regardless of nation. In their study, they observed 3 competent teachers over the course of 10 lessons each. These lessons were video recorded and analyzed qualitatively looking for patterns in teacher questioning sequences. What they found was that by recalling previously learned formulas, students could compare them to newer procedures, expanding on what they learned. Lower-order questions here serve a purpose that higher-order questions do not, they serve to bring the subject into context, which is equally as important as developing the discussion of it (Bingham, 2005; Koizumi, 2013).

However, according to my research, that is the extent to which lower-order questioning is described as beneficial to student learning. The articles synthesized largely disagree on the effectiveness of lower-order questioning. Authors generally agree that teachers ask primarily lower-order questions, even though teachers had no evidence quantifying or qualifying the effectiveness of such questioning practices (Aizikovitsh-Udi & Star, 2011; DeJarnette et al., 2020; Hsu et al., 2023; Roberts, 2020; Shahrill & Clarke, 2014; Yildizli & Günaydin, 2022). Returning to our consideration of discourse, overuse of TQ with lower-order questioning was found to produce lower quality discourse because the ability for a student to exercise their critical thinking is limited (Chikiwa & Schäfer, 2018). Thus, it is recommended that while teachers need to adopt a diversity of questioning practices, teachers should ask more higher-order questions than they currently do.

There were a few other categories that came about pertinent to student learning. These categories were open and closed-ended, and follow-up questions (Cumhur & Guven, 2022; DeJarnette et al., 2020; McCarthy et al., 2016). However, regarding student learning, TQ with these question types supported student learning primarily because of their effects on assessment or classroom management. Thus, these categories of questions have been included in those sections instead for a more focused approach to understanding the research on their effects.

For the purpose of student learning, it was important to define student learning. Most research articles on questioning (Aziza, 2018; DeJarnette et al., 2020; Roberts, 2020) defined student learning by categorizing student thinking based on whether they were a higher-order or lower-order question (Bloom, 1956; Webb, 2002). The general consensus based on research was that TQ with higher-order questions allowed students to practice, exercise, and display the critical thinking skills desired in contemporary learning. In contrast, lower-order questions were generally frowned upon because they limited a student's thinking to recall or memorization. Some articles found them to be useful as a foundational piece to higher-order questions, but again, the general consensus was that lower-order questioning did not generate meaningful student learning, especially because teachers tended to use them in overabundance. Overall, TQ with the purpose of student learning could serve to directly prompt or inhibit a student's learning or thinking based on the type of question asked.

TQ for the Purpose of Assessment

In this section, I will examine and synthesize the research on TQ for the purpose of assessment. Park (2020) defined formative assessment in her 2020 study of pre-service mathematics teachers as “an assessment activity that provides information about student learning to be used by teachers and by students’ peers as feedback to modify teaching and learning activities” (p.1). This definition strongly aligned with the way formative assessment was described in other studies, thus, it will serve as the definition of formative assessment in this paper. Within this section, I will explore the different examples and non-examples of TQ as assessment, its effect during case studies, and important considerations revealed by researchers.

Questions serve as a direct way to engage students in exercising their learning, communication, and critical thinking; they have to respond after all. Because of this, formative assessment and TQ align seamlessly because questioning prompts the student responses teachers want to understand. TQ allows teachers to understand a student’s mathematical thinking directly. In her study, Park (2020) observed the questioning practices of pre-service teachers undergoing university teacher certification; in this research, she watched as pre-service teachers developed the ability to use conversations as informal and formative assessments. What Park’s study (2020) and Shahrill and Clarke (2014) found was that most short response questions do not provide information about student thinking at all, defeating the purpose of a formative assessment. Thus, before talking about the effect that teacher questioning for the purpose of formative assessment can have, it is important to define what types of questions can serve as formative assessment and what types cannot.

Examples of questions that do serve as formative assessment (FA) appear in multiple case studies aside from just Park’s (2020). In an observation of 4 pre-service teachers in Turkey, Cumhur and Guven (2022) do an extensive analysis of questions asked within the classroom. In one case, a pre-service teacher asks, “Is there any other solution? In what other way can we solve this question?” (p. 983). This open-ended question was proposed to the class, prompting the students to explain different ways to solve for a missing angle inscribed in a triangle. After asking the question, the teacher received both short and long responses; one in particular exemplifies the idea that TQ can serve as a form of FA. One of the students in response replied, "I consider the other one as 30 degrees and I find there. We subtract it from 180 degrees" (p. 983). After hearing this student's response, the teacher is able to justify directly that the student has understood the concepts.

In an extremely extensive case study of 90 teachers in China, Ni et al. (2014) came to a similar conclusion. Using TQ with higher-order questions, teachers in China could pursue not only student solution methods, but they were also able to pursue the multiple solution methods present within the classroom. By questioning in such a way, there was more participation and independence in thinking. Both Cumhur and Guven (2022) and Ni's (2014) imply questions can be used to explore student thinking; these questions were considered by other studies as probing questions.

Probing questions serve as one of two major categories for TQ as formative assessment. A major component of formative assessment is, as mentioned earlier, a task that provides teachers and peers with information on student thinking. Franke et al. (2009) make this student thinking elicitation the center of their study, going as far as titling it "Teacher Questioning to Elicit Students' Mathematical Thinking in Elementary School Classrooms" (Franke et al., 2009). In this study, they follow three teachers in Southern California as they use TQ to elicit and extend their mathematical thinking. What they find is that the benefits of probing questions are straightforward. They enable teachers to more fully understand student thinking. However, they also add to a previous sentiment; asking only one question is not enough to fully understand student thinking.

This insight leads to the second category for TQ as formative assessment, follow-up questions. In conjunction, these two question types serve to complete the definition of formative assessment. Probing questions help teachers understand student thinking, and then asking follow-up questions that are more personal to students modifies instruction to fit their needs. Franke et al. (2009) and Mahmud et al. (2021) exemplified how these questions work in tandem in their studies. In Franke et al. (2009) one teacher begins solving an equivalence problem of whether 200+1 = 1+200 by asking “Who wants to share out their answers?” This elicits students to respond, then once a student responds, she follows with a question that could be considered both a probe and a follow-up, “What are you talking about? Could you explain what numbers you are talking about? (p. 386)” Finally, when the student’s individual solution method is clear she asks a more specific follow-up question, “Two and the 1 like this are partners?” Through this sequence of probing and follow-up questions, she is able to assess whether a student understands that both mathematical expressions are equivalent, and she has modified instructions using questions to ensure that the student and others in the classroom share that understanding. Mahmud et al. (2021) came to a similar conclusion as they follow six primary school teachers in Negeri Sembilan, a Malaysian state. Teachers used questions to assess student understanding before then improving the quality of their teaching and the quality of student learning. Whether a student’s answer was accurate, inaccurate, or incomplete, teachers could plan interventions to support this understanding. They add that this formative assessment conversation should not focus on just answers alone, but also a more holistic approach to student learning, including knowledge, skills, and values so that teachers have a better understanding of all aspects of the student’s ability.

Research on probing questions and follow-up questions as formative assessments is “relative and not absolute” (Mahmud et al., 2021; see also Franke et al., 2009), their effectiveness was relative to many variables such as student participation, context of the classroom, and ultimately how students respond or do not respond within the classroom. One other aspect of relativity, discussed in another study, is in the development of a teacher's ability to ask these questions. In Yenmez et al. they oversee the professional development of 10 high school mathematics teachers in Turkey. This professional development followed a five-month cycle of continual teacher planning, implementation, and reflection. These kinds of question types asked teachers to invite student participation, explore student thinking, and evaluate this thinking. In early implementation of TQ as formative assessment, teachers often did not pay attention to solution methods, while in later implementation they did (Yenmez et al., 2018). They began to be more critical of their influence on student solution, one teacher asking themselves why all groups used the same solution method in one of their modeling activities. Moments like these support Yenmez et al in their final suggestion that modeling activities can be used in pre-service teacher training and professional development to improve teacher questioning practices for purposes such as formative assessment.

As defined in Park (2020) formative assessment (FA) in its essence focused on two main points: the ability of a task to help students understand student thinking and use that information to modify instruction to better student learning. TQ with probing questions and follow-up questions encompassed that essence by directly and immediately involving students in that process. By asking probing questions, teachers could elicit class wide engagement to explore student thinking and the multiple solution methods in the classroom (Ni et al., 2014). Whether answers were accurate, inaccurate, or incomplete, teachers could then ask follow-up questions to modify instruction to ensure that the individual student better understands the topic and in some cases make that understanding class room wide (Cumhur & Guven, 2022; Franke et al., 2009;

Yenmez et al., 2018). However, this form of formative assessment was effective dependent on many variables such as student willingness to participate fully, their responses, other classroom contexts, and a teacher's own understanding of how to use these questions. Through the use of professional development it could improve a teacher's ability to use TQ as a type of formative assessment that betters student learning given the right contexts (Yenmez et al., 2018).

TQ for the Purpose of Classroom Management

In this section I will examine and synthesize the literature on TQ for the purpose of classroom management. Previously, I discussed how TQ can shape the types of learning that occurs within the classroom. This could be done by changing the richness of discussion or using probing questions to make more informed decisions about how to modify classroom instruction. Using Martin's (2016) analysis of evidence-based approach to classroom management, these effects that TQ have on the classroom can be considered as classroom management. While the exact definition of classroom management changes depending on the study reviewed, Martin et al clearly defined that the main focus of classroom management "should be on the collective success of students and teachers ritualizing effective routines and practices that define the classroom community (Hickey & Schafer, 2006, as cited in Martin et al., 2016). "Using focus as the main metric for classroom management, within this section I will explore how TQ practices affect discourse, climate, and ultimately classroom management based on how teachers utilize questioning.

Classroom discourse, also defined as student talk, is an important aspect of classroom management; this discourse was heavily affected by differences in TQ practices. Research generally agreed that allowing student talk opportunities contributed to the collective success of students, whether they were actively speaking their own mathematical ideas or actively listening (cite here). In a study of Brunei teachers, Shahrill and Clarke's (2017) examined the teaching practices of four secondary teachers recognized by principals as competent at teaching mathematics. Their primary focus was to examine how often teachers and students talked during public interaction segments, such as classroom instruction, and their secondary focus was to examine any issues emerging from teacher perspective on student questioning and teacher perspective on their own questioning. Shahrill and Clarke found that not only was there a difference between how much teachers believed they talked and how much they did, but also that student talk was almost completely passive. While observing four teachers of a total of 408 student talk/utterance opportunities, a staggering 91.9% of all student talk opportunities were between one to four words.

This form of discourse shows heavy restrictions in not only how much students talked, but also the form in which they talked, primarily only as a response to TQ. Richards (1991, Chapter 2) in the book Radical Constructivism in Mathematics Education, noticed this same restriction during a 10th-grade remedial tutoring session. He found that traditional TQ practices restricted student talk, and he says further that it is also important to recognize that this restricted student talk cannot qualify as a classroom conversation if teachers are merely saying words at students (Richards., 1991, Chapter 2). He argues that a *consensual domain,* such as shared context or a shared classroom structure, was necessary in order to have effective communication (Ernst von Glaserfelt et al, 1991). In an observational study on technology and non-technology supported classrooms Yilmaz and Cakiroglu (2024) analyze the differences between these classrooms. What they found was that in both cases, visual representation served as a form of channel for teachers and students to discuss questions (Yilmaz and Cakiroglu, 2024). The way teachers employ these channels, consensual domains, and ultimately contexts is what dictates the management of a classroom's discourse.

There were two studies that analyzed the differences in TQ practices based on country. Both studies utilized nationally available videotaped lessons, in Koizumi's (2013) study they used German and Japanese classroom recordings, while Kawanaka and Stigler (199) used German, Japanese, and United Sates of America classroom recordings. Because their results were similar between studies, Kawanaka & Stigler's (1999) more extensive study will be the one discussed. Interestingly enough, their study was actually composed of two studies; the first study focused on patterns of classroom discourse between the three cultures, and the second study focused on qualitative descriptions of higher order questions. What they found in the first study was that there was a statistically significant difference in how much teachers talked between cultures. In the German recordings, they found that 69% of classroom utterances were by the teachers, while in Japan and the US respectively, 83% and 74%. They also found that the average student response length was longest in Germany, with an average of 6.72-word responses, with Japan and the US being 5.35 words and 3.43 words respectively. This is a significant difference in how much teachers and students talked differing by culture; it is clear they are managing the classroom differently. Kawanaka and Stigler go on to say that this is because there is a difference in pedagogical goals each teacher is emphasizing.

In the 2nd study of Kawanaka and Stigler (1999), they analyzed the qualitative differences that TQ practices had on the classroom by culture. For example, in the United States, classroom recordings, they found that between the 30 randomly selected recordings, generally, teachers in the US emphasized the importance of recalling and applying mathematical principles rather than individual ideas and thinking processes. This differed from both the findings on Japanese and

German lessons; they defined this style of learning as convergent problem-solving, in which everyone is converging towards one answer. In contrast, they referred to Japanese classrooms and German classrooms as divergent-problem solving. In their example of a German lesson, students were asked to find paths for a ship to sail towards the harbor. The teacher facilitated students to explore their solution methods rather than apply a prescribed formula to have all students solve in one way. This led to more student talk and longer student responses, because the teacher was facilitating the discussion of such. However, it was noted that while the teacher was facilitating discussion, ultimately, the teacher remained the primary authority of knowledge in the classroom. The recordings of Japanese classrooms led them to a different generalization. They found that Japanese teachers primarily emphasized the importance of thinking about how to solve a problem rather than solving the problem itself. This looked like teachers explicitly giving wait time, asking students to present their thoughts, and understanding the thought processes of others. In this classroom, students were encouraged to evaluate each other. This was a completely different pedagogical approach to the US teachers, who used questioning to direct students towards an intended answer and evaluate them accordingly.

Tarasenkova et al. (2023) also found general pedagogical approaches for TQ practices with their survey on 173 teachers in Turkey. They looked at variables such as semantic support, goals of questions, and teacher attitudes towards questions. They found that while all teachers in the study used questions when teaching and learning mathematics, there were a plethora of independent variables that could affect students. With 35 different variables, of the ones focusing on questioning strategy, the most believed pedagogical approach to questioning was that questions “encourage not only the application of the acquired knowledge, but also generalizations and the establishment of interdisciplinary and intradisciplinary links in teaching mathematics" (Tarasenkova et al., 2023, p. 239). This belief seems to be a middle ground between the approaches of the teachers observed in the US and those in Germany (Kawanaka & Staggler, 1999). Teachers in Turkey want students to be able to apply formulas in principle while *also* being able to make generalizations between multiple disciplines. Once again, a different pedagogical reason to use TQ to manage the classroom and its success.

Of these different pedagogical approaches, specifically between those in Kawanaka & Stigler's (1999), an interesting aspect of the classroom arises, one of authority and evaluation. This raises an interesting aspect of the classroom, one of authority and evaluation. In Kawanaka and Stigler's (1999) study, they found that the recordings of US and German teachers indicated that the teacher remains the primary authority in evaluating student answers. In contrast, they found that Japanese teachers emphasized the importance of having students evaluate the answers of one another; Zhuang and Conner (2022) similarly find that they could use rational questions to encourage students to do the same. Using rational questions and argumentations, they found that students could engage with each other rather than having teachers be the center of all conversations; there was rich discussion. Students were either supporting their mathematical thinking with reasons, or they were listening to understand and challenge the thinking of others. Di Teodoro et al. (2011) agreed with this sentiment in their study of elementary teachers and students. Student learning occurred whether they were the ones answering the question, listening, or asking questions. This provided ownership over the questions and learning occurring in the class. In this way, students and teachers shared the authority of evaluation in the classroom. The classroom became one in which students and teachers shared joint authority.

Strongly present within constructivist classrooms is the idea of the teacher as facilitator of learning rather than the evaluator or director of it (Ernst von Glaserfelt, 1991; McCarthy, 2016). In Hill's literature review of the study of questioning techniques as instructional practice, she finds that the teacher must make the desire for a positive and collaborative climate explicit. This swaps the role of student and teacher. Students gain trust in being able to ask questions and discuss their thinking without ridicule, and teachers take on the role of listener to understand student thinking. With a strong understanding of student thinking and Mathematical objectives, teachers can leverage this to benefit classroom discussion and management; McCarthy (2016) called this the leveraging teacher. As long as this creates collective success within the classroom, this would also be considered effective classroom management, even though it differs from the traditional structures present in Mathematics classrooms. It must be said that while the idea of teacher as facilitator has been introduced and reviewed in many studies, the studies read did not provide any compelling quantitative or qualitative evidence. Aizikovitsh-Udi & Star (2011) were looking for these results in their case study of two teachers of junior high Algebra 1 classes. By observing two teachers with different styles, Aizikovitsh-Udi & Star looked to compare the "traditional teacher vs leveraging teacher". While they can describe the differences between these types of teachers, their results do not indicate any definitive differences in the success of students in the classroom. It cannot be said that becoming a facilitator of classroom discussion undoubtedly leads to richer classroom discourse.

Even through utilizing higher-order questions, probes, and facilitating principles, it is still not always the case that asking higher-order questions leads to richer classroom discourse. In Robert's (2020) case study of teaching mathematics in classrooms with English Learners, it was important that teachers transformed not only their questioning practices but also how they structured the classroom to respond to these practices. After multiple professional development sessions, the teachers' questioning practices seemed to transform, but the discussions did not.

Roberts concludes that this is because while the questions changed, both students and teachers were not familiar with the structure, attempting to expand their learning. Since students did not know how to respond, they needed someone to model what a good explanation or justification looked like. Teachers in the study stated that while they normally tended to step down the rigor of their questions when addressing English learners, by modeling how to respond to higher-order questions, such as revoicing, they began to notice differences in how students engaged and responded. Eddy and Kuehnert (2018) in their literature review of the advancement of teacher questioning over time also find that modeling these *sociomathematical norms* is necessary, especially because students are most likely used to traditional funneling patterns in which student discourse is funneled towards one right answer. They go on to say that when teachers are looking for specific answers, students guess at what the teachers want, a correct way of thinking. Modeling sociomathematical norms within the classroom, in addition to changing the questioning practices, created a classroom environment in which more students were set up for success. It focuses student attention on the ideas presented rather than ideas like guessing what the teacher has in mind (Eddy & Kuehnert, 2018).

Teacher questioning practices, in many ways, shape the structure and bounds of the classroom environment. Traditionally, through the overuse of closed-ended and lower-order questions, students primarily respond to TQ with one to four-word responses, leading to poor student talk. The types of questions asked within the classroom shape the classroom discourse and the talk that permeates. Just as important was the teacher's emphasis on different types of Mathematical understanding, as shown by studies that analyzed differences in classrooms by culture. Differences in emphasis changed not only student talk but the way that students and teachers interacted; teachers could become facilitators to learning, and students could become evaluators of each other. This student-teacher joint authority could create richer discussion on the pretense that these new contexts and structures were modeled and normalized within the classroom. Ultimately, TQ practices holistically were what could shape the classroom, not simply asking different questions, and their effects could create richer discussions that benefit the collective success of both student and teacher.

Summary

The research on TQ showed that ultimately, mathematics teachers asked questions for three purposes: to improve student learning, as a form of formative assessment, and as a means of classroom management. Different types of questions serve to affect different purposes. For the improvement of student learning, teachers used the categories of higher-order and lower-order questions to draw the bounds and elicit different levels of critical thinking. With formative assessment, teachers could use a sequence of probing and follow-up questions to elicit student thinking and make decisions based on mathematical understandings within the classroom. Implicit within all of these types of questions was a teacher's attitude and emphasis. Different cultures emphasized different mathematical understandings, such as the application of principal formulas or the importance of being able to understand how to solve problems rather than simply solving the problems themselves. For this reason, making explicit and modeling the kinds of responses teachers were looking for was important in helping students succeed and managing classrooms.

Action Plan

My literature review examined the research on the purpose of teacher questioning in mathematics classrooms. In that research, three major themes emerged. As follows, the three themes that emerged were Teacher Questioning for the purpose of 1) student learning, 2) formative assessment, and 3) classroom management. The action tables following outline recommendations the research suggested, my experiences with the practices anecdotally, and my suggestions after having synthesized both.

I currently work as a secondary mathematics teacher at a school in the Pacific Northwest. For privacy concerns, I will refer to the school as the League of Legends Academy (LoLA), an obvious pseudonym. The school is open to elementary, middle, and high school students, I primarily teach middle school students. LoLA is an academy school with a smaller student population of 750 students and a proportionally small teacher staff of 20 teachers. This school is an academy in which different types of contemporary learning models, such as project-based learning and inquiry, are utilized and professional developments are constantly developed and tested.

Additionally, my school partners with universities in the region to support pre-service teachers and counselors. In the spirit of innovative teaching methods, I was hired as a first-year teacher due to my interest in inquiry and constructivist teaching methods, meaning I have free rein over most, if not all, that occurs within the classroom. In the following sections of the action plan, I will go into detail, summarizing research suggestions and my learnings before proposing actionable ways of improving practice.

Teacher Questioning for the Purpose of Student Learning

In this section, I examined what research claimed as best practice regarding teacher questioning for the purpose of student learning. Teacher questioning practices directly provide students opportunities to exercise skills such as problem-solving, critical thinking, mathematical creativity, literacy, and understanding of mathematical application. These skills are what I define as student learning. With student learning defined, research generally suggests that more professional development or training with an explicit focus on questioning should be provided to teachers. This is because an understanding of the questions teachers ask has a large effect on the learning that occurs in the classroom. Below are also details involving the practice existent within my own school and my recommendations for improving TQ specifically for student learning.

Table 1

Teacher Questioning for the Purpose of Student Learning

What the research says…	**What my school does…**	**What I recommend…**
The research suggests that teachers undergo training to learn about the different types of questions and how they affect student learning. (Franke et al., 2009; Park et al., 2020)	LoLA does not provide training about teacher questioning in mathematics Classrooms.	Districts should provide training to help Mathematics teachers understand the different types of questions they can ask students and their effects on student learning.
The research suggests that asking open-ended questions provides students with more opportunities to exercise critical thinking, problem-solving, and mathematical creativity. (Aziza, 2018; DeJarnette et al., 2020)	The mathematics teachers in my department primarily ask lower-order questions during discussions to ensure students are continuously engaged in classroom learning.	Teachers should track the types of questions asked during lessons with the purpose of assessing whether they ask enough open-ended questions for students to exercise critical thinking.
The research suggests that mathematics teachers plan higher-order questions before executing lessons. (Mahmud et al., 2021; Shahrill & Clarke, 2014)	The teachers in my department do not discuss higher-order questions before executing lessons, they reference the curriculum teacher guide for possible questions to ask.	Teachers should cross-reference both the teacher guide and other teachers in the department to decide whether core concepts are addressed with questions that emphasize higher-order thinking.

Teacher Questioning for the Purpose of Formative Assessment

In this section, I examined what research claimed as best practice regarding teacher questioning for the purpose of formative assessment. Formative assessment, put simply, is any method for teachers to assess a student's understanding of a concept with the intention of modifying future instruction to best support the students or to give the students grades. TQ as formative assessment, can be a straightforward way to understand how much a student understands about mathematical concepts. Even if the result of a problem may not be correct, by asking follow-up questions, TQ allows us teachers to assess the completeness of their understanding and immediately modify instruction during one-on-one sessions. Research has many different suggestions regarding using questioning as formative assessment; they fall into three categories. They suggest professional development to help teachers understand the types of follow-up questions useful for probing and supporting the students' understanding. They suggest teachers ask more follow-up questions in general, and finally, they suggest giving students more wait time to develop their responses. Below are also details involving the practice existent within my own school and my recommendations for improving TQ specifically for formative assessment.

Table 2

Teacher Questioning for the Purpose of Formative Assessment

What the research says…	**What my school does…**	**What I recommend…**
The research suggests that teachers need to ask additional follow-up questions to understand student mathematical thinking holistically (Cumhur	The mathematics teachers at LOLA ask primarily leading questions to support students in reaching the solution that the teachers have in mind.	I recommend that teachers ask more follow-up questions to explore student thinking and also give students answer keys so that they can give themselves feedback

& Guven, 2022; Mahmud et al., 2021)		regardless of the solution method.
The research suggests that teachers should give more wait time when asking follow-up questions so that students can communicate their thinking (DeJarnette et al., 2020; Roberts, 2020).	The mathematics teachers and teachers in other departments have mentioned and practiced giving additional wait time to students.	I recommend that my school continue to stress the importance of wait time in allowing students to generate more complete and individualistic answers.
The research suggests that teacher educators should help Pre-Service Teachers develop an understanding of how to use teacher questioning to generate informal formative assessment conversations (Aydogan Yenmez et al., 2018; Park et al., 2020).	The teacher educators at my university did not help me understand how to use questions as informal formative assessments.	Teacher educators at universities should help teach Pre-Service mathematics teachers how to use question types such as probing questions and open-ended questions to help understand student thinking.

Teacher Questioning for the Purpose of Classroom Management

In this section, I examined what research claimed as best practice regarding teacher questioning for the purpose of classroom management. Indirectly, teacher questioning practices influence the types of discourse and learning that occur within the classroom. In this way, TQ affects the classroom environment and atmosphere revolving around mathematics discussions. For example, a teacher might ask a closed-ended question but ostracize a student for stating an incorrect answer. In the same question, a more questioning practiced teacher might ask a follow-up question, with more interest in the process rather than the result. Research suggests that teachers should be planning these questions intentionally and in advance so that they can not only be prepared to facilitate the kinds of discussions they produce, but also so they can model the types of discourse they want to see become the norm. Below are also details involving the practice existent within my own school and my recommendations for improving TQ specifically for classroom management.

Table 3

Teacher Questioning for the Purpose of Classroom Management

What the research says…	What my school does…	What I recommend…
The research suggests that teachers should model socio-mathematical norms for teacher questioning, such as how to respond to a higher-order question and how to revoice another student's response (Di Teodoro et al., 2011; Eddy & Kuehnert, 2018).	One of the teachers in my department provides questions and sentence stems so that students know how to respond to questions. Other teachers in the department do not model or provide student discourse support.	I recommend that teachers make the types of questions they will ask students explicit at the beginning of the year and model the types of responses these questions can have. Additionally, I recommend that teachers keep sentence stem resources available for students to access during class time.
The research suggests that teachers learn how to utilize different questioning strategies so that they can handle different types of discourse (McCarthy et al., 2016; Shahrill & Clarke, 2014).	The teachers in my department do not discuss the different types of questioning strategies the others use. Thus, the teachers in my department usually stick to their preferred questioning strategies to keep classrooms engaged.	I recommend that teachers in the mathematics department spend time discussing the types of questioning strategies each teacher prefers, their reasons for the preference, and the effect it has on classroom discourse.
The research suggests that teachers should plan questions in advance with the purpose of ensuring students understand the context and language (Bingham, 2005; Chikiwa & Schäfer, 2018).	The teachers in my mathematics department do not plan questions in advance.	I recommend that teachers plan a variety of questions for both the introduction and mastery of a topic to ensure that students understand the context and mathematical language.

Summary

In this section, I looked at recommendations from the literature and analyzed the LOLA to see how practices reflect those recommendations. In general, I found that research and my site were misaligned regarding their TQ practices. The need for continuing education and professional development centered on questioning will continue to be important in closing the gap between research and practice. I will now examine the literature more closely in the discussion section.

Discussion

Throughout the research, it was evident that teacher questioning (TQ) was an important aspect of the mathematics classrooms. Teachers used their questioning practices for many reasons; these primarily fell into three purposes: questioning for the purpose of student learning, formative assessment, and classroom management. It was important that teachers explored and utilized different types of questioning to broach the results they were seeking. For instance, it was found that higher-order questions and open-ended questions produced higher quality discourse with statistically more student discourse, and allowed students the opportunity to exercise critical thinking skills such as mathematical creativity (Aizikovitsh-Udi & Star, 2011; Aziza, 2018; DeJarnette et al., 2020). While there were a few articles that argued for the use of lower-order and closed-ended questions as a foundational piece for student learning and social scaffolding, research was lacking in this department largely. Similarly, research that explored quantitative effects on TQ practices was lacking. In the next section, I will return to the questions I posed in the rationale, the ones that propel this research.

Discussion of Findings

Central to this literature review were the three focal questions prompting the research. These three questions are as follows. When analyzing mathematics TQ generally, in what ways are practice and theory aligned or misaligned? What does research find to be important considerations for mathematics teachers when asking questions? In the research, how does asking open-ended questions affect the learning of students within mathematics classrooms? These questions will be answered using what I found within the research, experiences at my site, and my personal opinion as a professional in the field of education. I will then conclude with an analysis of my perceived lack of quantitative and substantive evidence on teacher questioning within the research, implications for educators and further research, and the limitations of my literature review.

Alignment or misalignment of practice and theory

The first question I posed in my research was, when analyzing mathematics teacher questioning practices generally, in what ways are practice and theory aligned or misaligned. Within both my time at university and as a practicing educator, the echoes of *best practice* continue to reverberate anywhere you might look. This search for best practice prompted not only my research but also further investigation into the best teacher questioning practices and evidence to suggest that these practices were true. The first question I posed in the rationale was, when analyzing mathematics teacher questioning practices generally, in what ways are practice and theory aligned or misaligned? In my research and personal experience, I found that practice and theory are mostly misaligned within mathematics classrooms with small pockets of alignment.

In my research, 13 articles suggested that teachers ask more higher-order or more open-ended questions. Though both higher-order questions and open-ended questions differ by their metrics, researchers often used them synonymously. This, however, was not abnormal because they produced similar effects. More often than not, both question types gave students the opportunity to exercise their communication skills and agency, engage in higher-order thinking, and express mathematical creativity. For example, in Aziza's study (2018), through the use of open-ended questions, she observed that asking open-ended questions broadened the horizons for answers collected from seven and eight-year-old children. Other studies, such as Hsu, also stressed the importance that students themselves practice exercising Mathematical creativity because staying passive recipients may not help them develop critical thinking skills (Hsu et al., 2023; Mahmud et al., 2021).

Asking open-ended questions also serves to benefit the teacher as well. Asking open-ended questions as follow-up questions and probing questions allowed teachers to leverage student understanding to modify instruction and challenge students thinking (Al, 2021; Cumhur & Guven, 2022; Franke et al., 2009). For example, in Franke et al.'s study she observed as one student made sense of the commutative property of addition. During a share out one teacher asked a student to explain further with the question "What are you talking about? Could you explain what numbers you are talking about?" (Franke et al., 2009, p. 386). In the student's response to the teacher's follow-up sequence, she explained that in the equation "$200 + 1 = 1 + 200$", she saw this as true because there were "partners" (Franke et al., 2009). This response allowed the teacher to uncover student thinking and make informed decisions as to whether students understood the concept at hand. These effects on student learning and formative assessment make asking more higher-order and open-ended questions strongly justified. However, while the effects of higher-order questions and open-ended questions have in mathematics classroom sound great on paper, I believe they are not as feasible in classrooms as researchers believe.

I see many ways that the research is misaligned with practice, largely because of how unrealistic its applications are. One consideration with open-ended questions and follow-up sequences mentioned was that they take a considerable amount of time to execute. Many observed teachers in the studies agreed or acknowledged this sentiment (Aziza, 2021; Hsu et al., 2023; Tarasenkova et al., 2023). At least within my district, class sizes and the duration of classes make this seemingly impossible with the expected number of standards students are asked to learn. Another consideration for open-ended questions that was not discussed in detail was the type of professional development needed to utilize open-ended and higher-order questions effectively. For example, the question “What is your name?” qualifies as an open-ended question, but it loses its effectiveness if it isn’t asked within an introductory period or if it is asked multiple times. While not a mathematical question, similar ones can be crafted using mathematical subjects. These contextual considerations to open-ended questions make them hard to utilize effectively within mathematics lessons. Finally, within research and practice, it was found that closed-ended questions were asked the most frequently but generally frowned upon by researchers. While there is a separate discussion to be had on this topic, I felt that researchers did not acknowledge the idea that closed-ended questions bring a subject into context for all students. This is an important reason mathematics teachers in my building use closed-ended questions.

While there were many ways that research and practice were misaligned, there were also pockets of alignment. Researchers argued strongly that mathematics teachers need to ask more higher-order and open-ended questions. In my practice at LOLA, the teachers are aligned in the sentiment, just not to the same extent that researchers suggest. Asking open-ended questions does create more fruitful discussion when used intentionally and sparingly. Since the teacher prompts the types of learning and discourse that students engage in, we are aligned in the idea that teachers need to be intentional with their questioning practice and that they should ask more higher-order and open-ended questions. These questions are the ones that give students agency. The last way that I found alignment was in the educational philosophy of constructivism, specifically through the use of follow-up questioning sequences. Teachers can, should, and do leverage what students know to create meaningful and lasting learning that is intimately personal to each student. This creates context shared between teacher and student, allowing communication to take place (Ernst von Glaserfelt, 1991). Seeing the few ways that research and practice are aligned reminded me that both parties have the students' best interest in mind.

Important Considerations for TQ in Mathematics

The second question I posed in my research was, what does research find to be important considerations for mathematics teachers when asking questions? Aside from the suggestion of asking more open-ended and higher-order questions previously. Researchers had practical and theoretical suggestions for teacher questioning practices. According to the research, there were four important considerations for teachers when asking questions. These suggestions were increased wait time, follow-up sequences and probes, developing shared contexts, and creating socio-mathematical norms that supported students in answering questions.

Giving students more wait time was the most frequent consideration given by researchers (Aizikovitsh-Udi & Star, 2011; Yildizli & Günaydin, 2022). The reason for this boils down to the kind of thinking needed for higher-order questions, that deeper thinking just needs more time (Yildizli & Günaydin, 2022). In Yildizli and Günaydin's (2022) mixed methods study using a large-scale teacher survey and an observation of two teachers, they analyzed the wait time of teachers in Turkey and their perspective on that wait time. What they found was that while the majority of 242 teachers believed their wait time was about 1 minute, in their observations, they found that the average wait time for questions was about 2 seconds. Only four of 242 teachers reported their wait time to be 10-15 seconds, this was a large discrepancy in perceived wait time and observed wait time. The importance of higher-order and open-ended questions justify a much larger increase in wait time than what was present in the study. Though no other authors shared this exact sentiment, Dillon (1983) writes that giving students more wait time after asking a question prompts students themselves to answer out of awkwardness. While not something to normally consider, this pressure also plays a role in the engagement increase by giving students more wait time.

Asking higher-order questions and giving students more wait time was followed in the research by the importance of follow-up sequences and probing questions. These questions were asked to explore the way a student understands the mathematical subject at hand and how deep that understanding runs (Cumhur & Guven, 2022; Mahmud et al., 2021). Following this was the consideration of becoming a leveraging teacher rather than a funneling teacher. This concept is best explained with the initiation, response, and evaluation (IRE) theory in which teachers initiate with a question, a student responds, and lastly, the teacher evaluates the correctness of the response. IRE is primarily used in funnel-style classrooms, where the teacher has an idea of both the correct answer and where the lesson concludes. Researchers found that in these classrooms, students are discouraged from responding due to the anxiety of being evaluated as right or wrong in their mathematical response. In contrast, the researchers talked about the teacher who asks open-ended questions and leverages students' mathematical solution methods to further classroom discourse and learning (citation here). Aizikovitzh-Udi and Star (2011) refer to this teacher as the leveraging teacher. They argue that not only is the leveraging teacher more likely to incorporate more advanced instructional strategies, but they're also more likely to ask questions that require more explanation and argumentation. This style of teaching is one that produces higher-quality discourse and more of it.

The final consideration researchers found important was in modeling the types of responses that teachers expected from open-ended and higher-order questions. In Robert's (2020) she observed that simply changing the TQ practices of teachers was not enough to produce a classroom with more engagement; teachers needed to be explicit with what they saw as a good explanation or justification. This was especially important for English learners who typically had questions modified, lowering the rigor, leading to more closed-ended and lower-order questions being asked, emphasizing recall rather than individual understanding. This modeling sets students up for success by supporting them in engaging with questions at hand.

In my school site, though the teachers continue to learn more about best practice, we have not considered the importance of shifting TQ practices towards asking higher-order, open-ended, probing, and follow-up questions. There have been no professional developments regarding the different effects these questions can have on classroom discourse, and further in the types of learning it can produce within the classroom. We have, however, spoken about the importance of wait time during professional development Wednesdays; teachers completely agree that giving students wait time is vital to ensuring they can engage in higher-quality discussions. A very realistic concern that researchers did not address was the practicality of spending so much time with not only higher-order questions but also probing/follow-up sequences. In Washington, one of the main concerns of mathematics teachers is keeping up with Common Core Standards pacing guides provided by OSPI. Many teachers I have met already feel like there is not enough class time to ensure students learn all of the mathematics topics they are being asked to.

During my first year of teaching, I have personally begun to notice the importance of probing and follow-up questions, especially during one-on-one tutoring sessions. Since I do not spend much class time giving direct instruction, I spend most of my time supporting students privately. I found that, at times, by asking them questions and challenging their thinking, they can gain deeper understandings of Mathematical principles than when I repeat direct instruction.

However, even though I see positive benefits in utilizing these TQ practices in my own practice, I see a limit to how much I can rely on them; this is for one reason. In a classroom of over 25 students, there will never be enough time to support the understanding of every single student in the classroom with questioning sequences. The research mentioned the ability of questions to help teachers modify instruction, whether answers were accurate, inaccurate, or incomplete. While this may be true, I find that because there is typically one teacher and over 25 students, this is impossible to do class-wide during instruction and class-wide during private conversations. Overall, I feel that these important considerations brought up by research are certainly those that can reap positive benefits with intentional practice and development, but it is not as simple as asking better questions or giving more wait time. The considerations for effective TQ practices are infinitely complex.

The Effects of Open-Ended Questions on Student Learning

The third question I posed in my research was, in the research, how does asking open-ended questions affect the learning of students within mathematics classrooms.

Throughout the literature, the idea of open-ended questions has been present. In all three themes, it presented itself in some way, such as its closeness to higher-order questions, its openness to probe student understanding, and its openness to open classroom discourse. I now return to the question of, in the research, how does asking open-ended questions affect the learning of students within mathematics classrooms? Aziza (2021) defined open-ended questions most clearly as “one that has more than one acceptable answer, can be solved through multiple solution methods, and can be developed into new questions” (Aziza, 2021, p. 35). These three aspects of open-ended questions will be critical to analyzing the effects of open-ended questions on student learning.

In the same study of Aziza's (2021), she observed that open-ended questions increased student discourse and invited them to express Mathematical thinking. For example, in a rather astonishing fashion, a year seven student responds to a teacher's question with "because that is in a category of 3n+1", while another student to that same question responded with "there is a different 3 in between them" (Aziza, 2021, p. 46). This difference in response is especially surprising because the first response indicates the beginning of understanding *sequences* in mathematics, a year nine concept by American standards. However, to return to the point at hand, by opening the floor to multiple acceptable responses, the students were able to express their different ways of perceiving the mathematics in front of them. This was beneficial whether a student understood it vaguely or deeply; in either case, they have the opportunity to exercise their thinking. These benefits were those outlined in the themes on student learning and formative assessment. For both student and teacher, researchers generally saw asking open-ended questions as beneficial to the classroom.

One distinction Aziza (2021) makes explicit that other studies did not was that open-ended questions can be developed into other questions. This is exactly what follow-up sequences and probes were intended for: a question or series thereof that help teachers understand and challenge student thinking. In Lovett's (2022) study of the relationship between teacher questioning and student generalizing, she mentions the importance of using a sequence of specific probing questions to help students connect their thinking and address misconceptions. These questions could fluctuate widely from gathering information to asking students to clarify, to extending their thinking about a subject. She mentions that this is because asking one question simply is not enough to understand a student's thinking; asking a series of open-ended questions was what led to teacher understanding of student thinking.

In practice, I largely agree with these benefits, especially the idea that asking open-ended questions invites students to participate regardless of their understanding of a concept. During classroom experiences, I have watched asking students to show their solution methods has helped others connect or draw from another student's thinking to their own. Asking open-ended questions has also helped me probe a student's understanding, it is especially helpful when wondering what a student has learned or been taught in previous years to build upon that knowledge. One way I see as detrimental to the classroom though, is how much time open-ended questions can take and the temporary disorder they can cause. Some teachers in the research also agreed with this (Hsu et al., 2023). However, overall, the effects of open-ended questions that research has shown seem to be interesting and hopeful. Coupled with the professional development, one should need to understand how to question effectively, TQ with open-ended questions might prove to be massively beneficial to the mathematics classroom.

A Lack of Evidence on the Effects of Teacher Questioning

What I found most jarring during my reading was the lack of evidence within the research. To me, the evidence provided by researchers felt lacking in the force to either prove that TQ positively affected student learning or shut out all other plausible outcomes. For example, in a large-scale teacher survey by Tarasenkova et al. (2023) the general consensus from over 173 teachers was that they ask questions for the benefit of the student, such as in encouraging them to make generalizations or helping them understand the essence of mathematics. However, it does not follow that students benefit from teacher questioning practices because teachers believe their questioning practices have this effect. Teacher perception and objective reality in student benefit are not logically equivalent. By what metric are they measuring student generalizations or understanding the "essence" of mathematics? In many studies, claims like these were loosely defined and even looser in their argumentation for that evidence. The purpose of teacher questioning in mathematics classrooms was clear, but the evidence of positive benefits in student learning, formative assessment, or classroom management was not.

Most evidence presented in studies was both anecdotal and qualitative (Aziza, 2018; McCarthy et al., 2016; Shahrill & Clarke, 2014). In McCarthy's (2016) study of two eighth-grade teachers in the USA, he observed that the mathematics discourse produced by TQ promotes *student collaboration* and *consensus*. In his case, the evidence provided was example conversations between student and teacher, ones in which these benefits were found to be present. Some studies found contrasting results, though, such as Robert's (2020) case with English learners. In her case, asking open-ended questions was initially found to produce the opposite result; it led to stalled conversation and a perceived need for teachers to reduce the rigor of the questions. This was then remedied using professional development, leading to increased engagement in classrooms. However, once again, Robert's evidence was anecdotal; it can not be generalized to the middle school population of the US. The plausibility of both TQ as beneficial and detrimental coexist.

A few persuasive studies showed the difference in engagement based on TQ with open-ended questions or closed-ended questions. This engagement was defined as *student talk* by Shahrill & Clarke in their (2014) study of Brunei Teachers. In this study, they found that over the course of 407 student talk opportunities, 375 or 92% of those student utterances were four words or less. This strongly suggests that students do not have the opportunity to exercise their communication of mathematics when asked primarily closed-ended questions. As for how studies could prove the proposed benefits of open-ended and higher-order questions, this remains unanswered.

In making those critical arguments for lack of evidence, I too lack the insight as to how a study might strongly prove the benefits of TQ with open-ended questions, higher-order questions, and the like. There was a study that mentioned the differences between a traditional teacher and a leveraging teacher. Yet even in a study that compared two teachers of different pedagogies, no quantitative evidence could be gathered, such as differences in test scores, because the population between classes is ultimately different. Furthermore, there would be no way to isolate TQ practices as the lone variable to success. This would be even harder if we in academia wanted to claim that constructivist practices are more holistic, meaningful, and deep; long-term studies would prove impossible when isolating questioning practices as the variable. In some sense, maybe quantifying how engaged students are is the only way to converse about the benefits. Student voice and satisfaction might be needed in justifying the benefits because, at the end of the day, it is them that TQ practices should serve, not just teachers.

Implications for Future Teachers, Students, and Schools

Both the research and my time at university have led me to believe that, as a whole, teachers are moving away from direct instruction. One of the main reasons for this is that direct instruction creates passive recipients of learning instead of students who take agency in the progression of their learning. TQ was shown by many studies to be one practice that can create that agency within students because questioning asks them to think. As such, future teachers and schools must begin by acknowledging the use of TQ as an effective way to further student learning and create classrooms that induce that learning.

However, this acknowledgement does not change a teacher's understanding of how to use questions, there are too many kinds of them after all. Research strongly recommends that schools have mathematics teachers undergo professional development to help them understand these questions. By undergoing this development, they would, one hopes, learn how each question is framed and the kinds of discourse they produce. Closed-ended questions only have one acceptable answer after all.

Three things should change within TQ practices generally to positively benefit the learning of students within the classroom. Firstly, teachers should undergo professional development to learn about the different types of questions, the discourse they can produce, and their effects on what students learn. For example, closed-ended questions can be used to assess memorization of facts, while higher-order questions can be used to measure a student's ability to make critical connections between different parts of mathematics. Secondly, teachers should dedicate more class time to questions, which includes more wait time and using more probing and follow-up sequences when supporting students one-on-one. This would grant students more agency in their thinking as the teacher becomes the facilitator rather than the bank. Lastly, teachers should outline what pedagogical purposes are most important to them. For example, when analyzing Japanese lessons, it was generally found that they emphasized the importance of metacognitive thinking, understanding how to go about solving the problem rather than simply solving it (Kawanaka & Stigler, 1999). Understanding our own general biases in this regard helps us to diversify the different kinds of mathematical understandings students can learn.

Implications for Future Research

What I noticed was that many studies argued for the implementation of more higher-order, open-ended, follow-up, and probing questions within the classroom. The effects of these questions varied from deeper student learning and increased engagement, allowing more informed teacher decision making, and creating classroom atmospheres more conducive for students to participate. However, most studies argued with anecdotal evidence, listing example questions and resulting conversations. Even though by intuition I agreed, their evidence felt sufficient to back up the authors' claims.

What this evidence looks like is still ambiguous, but I believe that it must inherently involve more student voice. There were multiple surveys done on teachers' understanding of the effect of TQ practices, but no surveys were done with students as the participants. Student surveys on the satisfaction of their learning may differ from the traditional funneling teacher to the modern leveraging teacher. This would add another perspective to understanding the differences between student learning and classroom management. Since most studies were anecdotal and qualitative in nature, it could have been done within the scope of their research.

Three things should happen in the future of TQ practices to benefit students. Firstly, researchers need to be clearer on not only the types of questions that qualify as higher-order, lower-order, open, closed, probes, and follow-ups, they need to be clearer about what types of responses qualify as ample justification by students. Secondly, researchers need to conduct more studies that quantitatively measure the differences between teachers who primarily use direct instruction and those who use inquiry models. These two pedagogies for teaching produce vastly different TQ attitudes and measuring how students engage with the content is one metric that should correlate directly to student learning. Finally, researchers should conduct more studies on the effects of TQ professional development on the management of the classroom. In my research, four studies analyzed the differences in TQ practices before and after professional development. Not considered in those studies was the effect on student discourse; looking at the differences in that discourse before and after professional development would prove useful in proving the positive effects of TQ.

Limitations of the Project

The seed for this research began when I read Radical Constructivism in Mathematics Education by Ernst von Glaserfeld (1991) in early 2024. When I was reading this book, what piqued my interest was the idea that everyone was constructing the way they saw and used mathematics. Constructivism said that, while there was no denying our external reality, as individuals, we organize our experiences in ways that are most convenient to us (Ernst von Glaserfeld, 1991). I began to wonder what it would take to understand the subjective and deeply personal worlds each student was building. It was not too long before I arrived at questioning as my solution.

Looking through the university library, ERIC, and EBSCO, the keywords for this research began with *questioning in mathematics classrooms*; they were then refined to *effective questioning in mathematics classrooms* and *inquiry in mathematics classrooms*, before finalizing on what was the most common way to refer to this work, *teacher questioning in mathematics classrooms*. Articles that involved questions from students were similar in volume but disregarded due to the scope and nature of this literature review. I felt that including student questioning would convolute the purpose of my research and should instead be done separately.

These 29 articles spanned from as early as 1999 to as recent as 2024, with 1 being a book by Ernst von Glaserfeld. This range made logical sense, considering that both radical constructivism and Bloom's Taxonomy increased in popularity in the 21st century. However, in my research, I found that teacher questioning was not as studied as project-based learning, problem-based learning, and inquiry. Personally, this felt like it led to ambiguity or lack of in both the evidence supporting teacher questioning and the clarity on its application.

Conclusion

One of the most beautiful aspects of mathematics is the art of critical thinking. Understanding how mathematics works has helped perpetuate STEM fields, such as technology, to become intertwined with human life. These novel and unique applications all stem from being able to use mathematics in interdisciplinary ways that push our thinking further. Thus, understanding that each student has their own way of perceiving mathematics is paramount to our time. Society wants critical thinkers to be able to solve global problems. It is important to give students opportunities to exercise their agency and critical thinking as early as possible.

Teacher Questioning (TQ) does just that, it creates opportunities and puts the experience of learning in student hands. In this paper, I have tried to address that very issue through an examination of literature. Within the review of literature, I found three purposes for TQ: 1) student learning, 2) formative assessment, and 3) classroom management. By examining suggestions made by the research and my school site, I recommended changes that should be made to improve TQ practices within mathematics classrooms. Finally, I discussed what the research and my synthesis had for my focal questions and implications for future teachers and research. Finally, I conclude that, while subjective, it is important for mathematics educators to realize the importance of their questioning practices within the classroom. The very questions they ask shape both the classroom and the learning of everyone taking part.

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