

# From Prompt to Practice: Using Artificial Intelligence to Support Productive Struggle in Elementary Mathematics Methods Courses

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## Abstract

This study examines the use of an artificial intelligence (AI) tool to support current and future elementary teachers in developing mathematical story problems, alongside the content knowledge and pedagogical strategies needed to facilitate problem-solving that encourages critical thinking, perseverance, and mathematical discussion. Specifically, MagicSchool.ai was integrated into elementary mathematics methods courses at a southeastern university in the United States: two asynchronous graduate sections for in-service teachers ( $n = 31$ ) and two in-person undergraduate sections for preservice teachers ( $n = 46$ ). Participants utilized AI tools to evaluate how their questioning techniques could enhance mathematical reasoning while maintaining cognitive demand and fostering productive struggle. Analysis of participants' course artifacts and reflections revealed how the AI tools strengthened their instructional practice by: (a) deepening their understanding of mathematical processes and scaffolding, (b) improving question types and sequencing, (c) broadening their exploration of diverse problem-solving approaches and opportunities for personalization, and (d) enhancing their self-reflection in facilitating productive mathematical discussions. Findings highlight AI's potential as a prompt generator and question-scripting partner, with recommendations for integrating AI into teacher preparation and K–12 classrooms to promote reflective, effective mathematics instruction.

**Keywords:** Mathematics Education, Artificial Intelligence, Productive Struggle, Teacher Education, Elementary, Questioning

## 1 Introduction

Mathematics learning is not a linear journey, but rather a journey marked by rough drafts, teachable moments, and celebrations (National Council of Teachers of Mathematics [NCTM], 2014). Along the way, students encounter opportunities for insight as well as mistakes, both of which are essential to building deeper understanding. When students have the skills and tools to engage in productive problem-solving and critical thinking, they strengthen their mathematical identities (Rhodes et al., 2023). For this reason, mathematics teacher education must prepare teachers with the knowledge and pedagogical skills necessary to guide and challenge students throughout this journey (Association of Mathematics Teacher Educators [AMTE], 2017).

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Methods courses are key in this preparation, offering preservice and in-service teachers space to work through problem-solving prompts, practice pedagogical strategies, and examine student artifacts. However, one persistent challenge remains: simulating authentic interactions between teachers and students. In particular, encouraging productive struggle—the process of grappling with complex or unfamiliar tasks in ways that build resilience, foster critical thinking, and lead to deeper understanding—can be difficult to practice in teacher education settings when opportunities to role-play authentic interactions with student thinking are limited (Hiebert & Grouws, 2007).

At the same time, advances in artificial intelligence (AI) present new opportunities to address this challenge. AI tools can be used to strengthen instructional practice by proposing scaffolding techniques, offering guided strategic questioning, and generating open-ended tasks that support multiple solution pathways—all of which are essential for promoting productive struggle and rich mathematical discourse (International Society for Technology in Education, 2024; NCTM, 2024). By serving as a teaching partner and tutor, AI has the potential to strengthen teacher preparation by helping educators build content knowledge and pedagogical strategies that foster students' persistence and engagement—central aims of this study.

In this study, AI tools were used in elementary mathematics methods courses to support current and future teachers in designing and facilitating mathematical story problems while deepening their understanding of productive struggle. Conducted at a university in the southeastern United States, the study included two asynchronous graduate sections for in-service teachers ( $n = 31$ ) and two in-person undergraduate sections for preservice teachers ( $n = 46$ ). The guiding research question was: *How do preservice and in-service teachers use AI tools to script teacher-student dialogue that facilitates productive struggle in elementary mathematics education contexts?* The shared task and insights drawn from teacher artifacts and reflections are presented to illustrate how these activities supported teacher learning and instructional practice. Additionally, recommendations for integrating AI into teacher education programs and K–12 classrooms are shared, highlighting its potential to foster more reflective, effective, and student-centered mathematics instruction.

## 2 Productive Struggle in Mathematics Education

Productive struggle in mathematics education refers to students engaging in challenging tasks that require effort, perseverance, and strategic thinking to develop deeper conceptual understanding, rather than simply seeking correct solutions (Hiebert & Grouws, 2007). NCTM's *Principles to Actions: Ensuring Mathematical Success for All* (2014) identifies supporting productive struggle as one of eight effective teaching practices, underscoring its importance in high-quality mathematics instruction. To engage in productive struggle, students need opportunities to draw on prior knowledge, confront challenges, and learn from their mistakes (AMTE, 2017; Casler-Failing et al., 2022). This approach aligns with the Four Rights of the Learner (Kalinec-Craig, 2017), which affirm students' rights to (a) be confused, (b) claim mistakes, (c) speak, listen, and be heard, and (d) represent their thinking in ways that make sense to them.

When classrooms embrace productive struggle, students move beyond surface-level procedures and engage in meaningful learning characterized by deeper conceptual understanding and increased critical thinking (SanGiovanni et al., 2020). Productive struggle also supports the development of mathematical agency and growth mindsets (Boaler, 2016; Dweck, 2006). By positioning students as capable thinkers and honoring the value of challenge, teachers cultivate mathematical resilience, encourage academic risk-taking, and promote authentic sense-making (Hiebert & Grouws, 2007). Ultimately, intentionally facilitating productive struggle helps create inclusive and empowering mathematics classrooms that equip all students for success (Murdoch et al., 2021).

The importance of productive struggle lies in its capacity to nurture a growth mindset, strengthen problem-solving skills, and support learning through mistakes—what Kapur and Bielaczyc (2011) describe as “productive failure.” When students grapple with complex mathematical problems, they develop resilience and persistence that contribute to more robust conceptual understanding (NCTM, 2014). In contrast, when instruction minimizes struggle by overemphasizing procedural steps, teachers may unintentionally create opportunity gaps that limit students’ engagement in reasoning and sense-making (Smith et al., 2021). Allowing students to wrestle with mathematical ideas through productive struggle enables them to take ownership of their learning and build confidence in their ability to construct and refine mathematical understanding (Baker et al., 2020; Dixon & Mahoney, 2024).

To effectively facilitate productive struggle, teachers must cultivate a supportive and equitable learning environment that attends to students’ diverse backgrounds, experiences, and learning needs (Townsend et al., 2018; Young et al., 2024). This includes selecting rigorous, developmentally appropriate tasks that invite challenge (Livy et al., 2018), offering strategic guidance without reducing the cognitive demand, and encouraging collaboration and mathematical discourse. Central to this work is establishing a classroom culture where mistakes are viewed as meaningful learning opportunities rather than obstacles (Rhodes et al., 2023). Teachers can support students as they navigate productive struggle by providing proactive scaffolds, posing open-ended questions, offering sufficient wait time, and using alternative representations (e.g., diagrams or visuals) to help students make connections and strengthen their reasoning (Jackson & Lambert, 2010). Recognizing students’ effort and perseverance, and providing constructive feedback that highlights progress, further reinforces a positive and growth-oriented environment (Warshauer, 2015b).

To meaningfully incorporate productive struggle into their mathematics classrooms, preservice and in-service teachers need opportunities to experience productive struggle firsthand and rehearse teacher–student interactions that mirror authentic classroom dynamics (Townsend et al., 2018). Mathematics methods courses offer a critical space for examining productive struggle from both the learner and instructor perspectives. Yet, facilitating such authentic experiences can be challenging, particularly when courses lack embedded, field-based opportunities to interact with students. These challenges are intensified in asynchronous online settings, where real-time exchanges and responsive teaching moments are limited. Despite these constraints, research underscores the importance of supporting productive struggle even in online environments (Casler-Failing, 2024; Warshauer, 2015a). This highlights the need for continued exploration of how AI tools might enhance teachers’ ability to engage in and facilitate productive struggle through simulated teacher–student dialogue. Accordingly, the present study investigates AI-supported pedagogical scaffolds, with a focus on productive prompts and scripting. Table 1 outlines question types and examples that can be used to promote productive struggle in mathematics.

**Table 1.** *Questions that Prompt Productive Struggle in Mathematics*

Question Type	Purpose	Examples
1. Understanding the Problem	Help students make sense of what is being asked	<ul style="list-style-type: none"> <li>• What is the problem asking you to solve?</li> <li>• Can you restate the problem in your own words?</li> <li>• What information do you have? What information do you need?</li> </ul>
2. Strategy Development	Encourage students to consider multiple approaches	<ul style="list-style-type: none"> <li>• What is one way you might start solving this problem?</li> <li>• Is there a strategy you have used before to solve a similar problem?</li> <li>• What would happen if you tried ____ (e.g., a connection made to a similar or previous problem-solving strategy)?</li> </ul>
3. Reasoning and Justification	Push students to explain their thinking and make sense of their methods	<ul style="list-style-type: none"> <li>• Why do you think that strategy will work?</li> <li>• What patterns or relationships do you notice?</li> <li>• Can you prove your answer makes sense? What evidence might you note to support your answer?</li> </ul>
4. Reflection and Revision	Support students in evaluating and revising their thinking	<ul style="list-style-type: none"> <li>• What part of your solution strategy are you most confident about?</li> <li>• If your answer seems off, what could you check?</li> <li>• Is there another way to solve this problem?</li> <li>• Which strategy do you understand best? Why?</li> </ul>
5. Normalizing Mistakes and Perseverance	Create a safe space for struggle and risk-taking	<ul style="list-style-type: none"> <li>• What did you try that did not work?</li> <li>• What did you learn from that attempt?</li> <li>• What is one thing you have figured out so far?</li> </ul>

## 2.1 Artificial Intelligence-Supported Pedagogical Support

Existing literature highlights the roles AI assistants can play in providing pedagogical support and examines how users perceive both the benefits and the tensions that accompany their use (see, e.g., Brady et al., 2024; Kim et al., 2025; Moldavan & Nafziger, 2024). When teachers have the skills to use AI effectively, these tools offer substantial advantages (Kerneža, 2023). AI can streamline time-consuming tasks, such as lesson planning, creating rubrics, differentiating instruction for diverse learning needs, grading reports, and routine communication, thereby freeing teachers to focus on instructional decision-making. Beyond efficiency, AI tools can also enhance teachers' professional practice by supporting writing tasks, enabling personalization, and fostering innovative instructional approaches (Floridi & Chiriatti, 2020; International Society for Technology in Education [ISTE], 2024). At the same time, responsible use requires attention to ethical issues, including academic integrity, plagiarism, and data privacy (Holmes et al., 2022; Tunjera & Chigona, 2023). As research explores

these critical concerns, it remains essential to investigate how AI is being leveraged to strengthen pedagogical practices and to evaluate the extent to which it effectively supports the goals it is intended to advance.

In Kasepalu et al.'s (2022) study on using an AI assistant in synchronous, face-to-face collaborative learning activities, the AI assistant proved beneficial in supporting teachers' pedagogical actions. Specifically, the AI assistant enhanced teachers' interactions during collaborations and interventions with students, enabling them to effectively implement the assistant's suggestions in various scenarios. In a related context, Pesce and Blanco (2024) conducted a study examining university students' perceptions during an experience using a chatbot. The advantages of using ChatGPT as an assistant in teacher training were attributed to aiding and refining one's ideas, designing strategies for contextualizing writing prompts, enhancing guidance and feedback, and co-constructing evaluation criteria. However, the study noted that while the AI assistant's support was valued, it could not replace the guidance and feedback provided by a teacher who is a specialist in the subject and has expertise in the students' individual conditions (e.g., prior experiences, cultural background, learning needs). Recognizing the importance of using AI tools to support and accompany rather than replace their work is supported by Wollny et al. (2021).

As AI tools become more deeply integrated into educational settings, it is increasingly important to examine how AI assistants can support teacher education in fostering productive struggle. Investigating how AI can offer real-time feedback, suggest targeted instructional moves, and provide alternative representations can help teacher educators better prepare preservice and in-service teachers to strengthen students' perseverance and mathematical reasoning. Emerging research can also inform strategies for incorporating AI-mediated activities that promote deeper mathematical thinking, supported by intentional scaffolding, strategic questioning, and open-ended tasks that invite multiple solution approaches (NCTM, 2024).

## **2.2 Scripting for Professional Noticing and Pedagogical Reasoning**

While pedagogical tools are available to help teachers refine their questioning techniques and strategies for supporting students in mathematics education, scripting—the practice of writing and revising dialogues—is of particular interest to this study, especially when used in conjunction with AI tools. Scripting provides both preservice and in-service teachers with structured ways to anticipate student responses, plan purposeful questions, and consider multiple pathways for facilitating mathematical reasoning (Kazemi & Franke, 2004; Lampert et al., 2013). By engaging in this practice, teachers can better align their instructional moves with NCTM's (2014) Standards for Mathematical Practice, referencing those that emphasize reasoning and making sense of problems. Through scripting, teachers can rehearse how they might respond to student misconceptions, press for justification, and foster productive struggle, moves that research shows are essential for developing deeper mathematical understanding (Boaler, 2016).

However, tensions exist in the practice of scripting, especially when scripts detail prescriptive responses or fail to account for the dynamic and uncertain nature of classroom discourse. While scripting can support teacher preparation and reflection, it may also constrain responsiveness if treated as a fixed plan rather than a flexible guide (Horn et al., 2015). Without opportunities to practice their scripts or engage with student responses, teachers might struggle to plan for or build on spontaneous student ideas or unexpected errors that emerge in real-time. This tension highlights the importance of viewing scripts as living documents, evolving through enactment, reflection, and collaborative inquiry, and considering best practices for using scripts as an instructional tool (Grossman et al., 2009).

In this study, scripting served as a practice-based learning tool to facilitate the development of

professional noticing and pedagogical reasoning. Professional noticing refers to a set of interrelated skills that enable teachers to attend to students' mathematical strategies, interpret the meaning behind those strategies, and make informed instructional decisions in response (Jacobs et al., 2010). When teachers write, revise, and discuss scripts with peers or mentors, they develop the capacity to notice and interpret student thinking, making instructional decisions that support students' problem-solving processes (Jacobs et al., 2010; Sherin et al., 2011). This collaborative scripting process also enables teachers to experiment with various methods of eliciting and responding to student ideas, particularly in moments of struggle and complex teaching situations.

In mathematics classrooms that prioritize reasoning and perseverance, scripting can be beneficial for planning and supporting productive struggle. Scripting provides teachers with the opportunity to design scaffolds and questions that maintain high cognitive demand while supporting students during moments of uncertainty or confusion (Jacobs et al., 2010). Nonetheless, this requires a careful balance: scripts must be designed to encourage struggle without prematurely reducing the challenge or providing too much guidance, thereby reducing a student's cognitive demand. In this way, scripting can cultivate teachers' capacity to orchestrate discussions that value sense-making, sustain engagement, and support all students in developing mathematical agency.

### 3 Methods

This study used qualitative case study methodology (Yin, 2014) to examine how preservice and in-service teachers utilized AI tools to script teacher-student dialogue that facilitates productive struggle in elementary mathematics teacher education contexts. The participants,  $N = 77$ , were enrolled in elementary mathematics methods courses: preservice teachers ( $n = 31$ , 40.26%) enrolled in two sections of an undergraduate, in-person course, and in-service teachers ( $n = 46$ , 59.74%) enrolled in two sections of a graduate, asynchronous, online course. The courses were offered at a university in the southeastern United States. See Table 2 for additional demographic information self-identified by the participants.

**Table 2.** *Characteristics of Preservice and In-Service Teachers*

Characteristics	<i>n</i>	%
<b>Gender</b>		
Female	74	96.10
Male	3	3.90
<b>Race/Ethnicity</b>		
White	62	80.52
Black	8	10.39
Hispanic/Latinx	5	6.49
Other	2	2.60
<b>Age</b>		
18–24	49	63.63
25–34	21	27.27
35–44	3	3.90
45+	4	5.20

Note.  $N = 77$ .

### 3.1 Procedure

The researcher created an AI Mathematics Module that had preservice and in-service teachers explore MagicSchool.ai, an AI-powered platform designed to support instructional tasks and promote student engagement and learning outcomes. MagicSchool.ai was selected because its platform offers over 80 tools to assist with lesson planning, assessment creation, rubric development, communication templates, and more. It is designed for use by both teachers and students and uses that dual perspective to support thoughtful and responsive teaching and learning. While the AI Mathematics Module consisted of four tasks, Parts 4–6 from Task 3: Explore AI Tools as a Student Learner and Tutor were highlighted for this research study (see Appendix A).

The targeted parts from Task 3: Explore AI Tools as a Student Learner and Tutor engaged preservice and in-service teachers in examining selected features of the free version of MagicSchool.ai, with attention to three tools central to this study. The first tool, Math Story Word Problem, allowed teachers to generate word problems aligned with grade-level standards and personalized to student interests. Participants evaluated the quality of the AI-generated problems, chose one to solve, and reflected on their own problem-solving processes. The second tool, Multiple Explanation, enabled teachers to explore alternative solution strategies by comparing the AI's methods with their own. This comparison supported deeper mathematical understanding and encouraged teachers to consider how such strategies could scaffold or extend learning for diverse students. Finally, the Custom Chatbot tool supported teachers in drafting a teacher–student dialogue that modeled how they might guide a learner through a story problem while effectively fostering productive struggle.

Using these tools, the task encouraged teachers to integrate creativity, content knowledge, and pedagogical reflection while exploring meaningful ways to incorporate AI into mathematics instruction. First, it positioned AI as a scaffolding resource, providing question prompts, analogies, and examples to help students persevere through challenging problems. Second, it promoted the exploration of multiple strategies and representations, reinforcing the idea that there is more than one way to approach a mathematics problem, which fosters flexible thinking. Third, the task encouraged a student-centered approach, highlighting how AI-generated scripts can support reflective, dialogic teaching that nurtures student confidence and autonomy. Fourth, it emphasized the role of productive struggle and mistake-making in mathematical learning, aligning with the principles of a growth mindset. Finally, by inviting teachers to reflect on the AI's output and compare it with their own thinking, the task supported deeper teacher reflection and thoughtful planning, reinforcing how AI can complement, but not replace, equity-focused instruction.

Responses to Parts 4–6 of Task 3: Explore AI Tools as a Student Learner and Tutor were analyzed using qualitative thematic analysis (Miles et al., 2018) to identify patterns in participants' engagement with the task. The researcher conducted the coding process using an inductive approach, allowing themes to emerge naturally from the data. Coding focused on participants' strategies, language, and reflections related to scripting productive struggle in mathematics education. Initial codes were then organized into broader categories, which were iteratively refined into overarching themes. To provide additional context and alignment, the analysis drew on established frameworks of productive struggle in mathematics (Hiebert & Grouws, 2007; Warshawer, 2015b), helping to connect emergent patterns to key principles such as perseverance, strategic support, and student agency in problem-solving. Appendix B presents the coding chart and examples illustrating how participant responses informed the development of these themes.

To enhance trustworthiness, participant debriefing and member-checking (Lincoln & Guba, 1985) were conducted with 10 participants across the sections. During member-checking, participants reviewed the overarching themes and were given the opportunity to make refinements and provide feedback.

All participants had agreed that the themes supported their shared experiences. While the coding was conducted by a single researcher, reliability was supported through the use of memos to document coding decisions and an iterative reflection process aimed at reducing bias (Grbich, 2013).

## 4 Findings

When working through the task, the preservice and in-service teachers used the Math Story Word Problem tool to create example story problems. After reviewing the examples, they reflected on how the story problems might interest their current or future students and meet their learning goals. Several participants commented on how they liked that the proposed problems reflected students' real-life interests. It is also important to note that while the participants appreciated the structure and relevance of the problems, several noted they would change the complexity of the numbers or the mathematics vocabulary. For example, one participant said, "I might change the numbers of this problem when first working with the story problem," and another shared, "I would possibly have to add some scaffolds... go over some of the vocabulary." These responses reveal that, while the Math Story Word Problem tool provides a solid foundation, participants were thinking critically about tailoring the problems to meet the varied needs of students. One participant even noted the need to correct the AI's output regarding geometric language:

I actually have a bit of an issue with this word problem because it says that the baskets are shaped like a circle and a square. Circles and squares are flat, but baskets are not flat. Instead, the problem should say the baskets are shaped like a cube and a cylinder because they are 3D.

Additionally, participants recognized that while the problems are helpful, they might need to be reworded to promote critical thinking or avoid confusion: "To make it more meaningful and more challenging, I would add additional questions," and "Most students would not understand how to solve both aspects of the problem and would probably get overwhelmed." These comments reflect an awareness of pacing and progression in instruction, showing that teachers are appropriately considering how to scale problem complexity.

After independently solving a selected story problem, they explored the Multiple Explanation tool to learn about other potential solution strategies that were AI-generated. They then used AI output to compare solution strategies and enhanced their mathematical knowledge. Most participants observed that the AI output aligned with their solution strategy. Furthermore, about half reported using AI's explanations to explore alternative ways of conceptualizing and communicating the content, noting that this could be "especially helpful for scaffolding students' learning and offering different ways to visualize and make sense of the material." Another participant noted, "It made me think about whether there is a different way to solve the problem without the standard algorithm, and I want to look into it more outside of this assignment."

With different solution strategies in mind, the task prompted participants to explore ways they might support a student who becomes stuck or shuts down when asked to solve a problem. All participants were able to generate example questions they might ask a student in such a dilemma. Then, they used the Custom Chatbot tool to generate other questions and provide guidance on what might be missing. Using the AI output as an aid, the participants wrote a teacher-student script, demonstrating how they might facilitate productive struggle. For instance, one participant posed the following initial questions: "What do you notice about the square basket? What do you notice about the circle basket? How many sides and corners do they have? What objects remind you of the square basket shape? What objects remind you of the circle basket shape? Why does the square basket remind you of \_\_\_?"



Why does the circle basket remind you of \_\_\_\_? Can you think of a way that squares and circles are different?” Table 3 illustrates how the participant used MagicSchool.ai’s Custom Chatbot tool to inform their instructional script.

Another participant posed the following initial questions: “What do you visualize/see in your math movie after I read the problem? Let us start by focusing on the first round, how many teams are going to be competing in the first round? Can you show me, using your counters, how many teams will be in the first round? Okay, now, if that doubles, can you show me with your counters how many teams will be in the second round? How can we continue to show each team doubling in the rounds? What does the word double mean? Have we used this term when multiplying by a certain factor? What is causing your frustration with this problem? What part of the problem are you having trouble understanding?” Table 4 illustrates how the participant used MagicSchool.ai’s Custom Chatbot tool to inform their instructional script.

*Note:* The bold font in the scripts and the mapped descriptors in the parentheses indicate the researcher’s observations, informing the comparative analysis of the script to the response output.

Tables 3 and 4 provide example response scripts informed by MagicSchool.ai’s Custom Chatbot tool. Next, four themes are examined that illustrate how preservice and in-service teachers leveraged AI tools to strengthen their instructional practice: (a) deepening their understanding of mathematical processes and scaffolding, (b) improving question types and sequencing, (c) broadening their exploration of diverse problem-solving approaches and opportunities for personalization, and (d) enhancing their self-reflection in facilitating productive mathematical discussions. These themes provide insight into AI’s potential to serve as both a prompt generator and a partner in designing effective questioning strategies that encourage productive struggle.

#### **4.1 Deepening Understanding of Mathematical Processes and Scaffolding**

Many participants noted that the questions they typically ask during problem-solving closely mirrored those generated by the Custom Chatbot’s output. Even so, the AI-informed questions prompted scaffolding related to extracting key information, interpreting the problem, and developing solution strategies. This is evident when comparing participants’ initial questions to those in the AI-supported script shown in Tables 3 and 4. While many questions were similar in intent, participants observed differences in how the questions were sequenced or contextualized. One participant reflected, “The questions that I asked are very similar to the ones given using the AI tool. Both sets of questions walk the students step-by-step to try and get them to produce the answer on their own,” acknowledging the importance of having students arrive at solutions on their own but with teacher guidance through targeted questioning.

While questions may have been similar, some noted that observing different ways of scaffolding questions provided insight into effective strategies for scaffolding mathematical thinking. One participant noted, “I believe I scaffolded my questions, but now I see how I could be leading my students too much, which may not be a scaffold if it reduces the cognitive load.” This reveals an awareness of the delicate balance between guiding students and encouraging independent thinking when provided support. Another praised the Custom Chatbot tool for guiding their script, saying, “It gives you an opportunity to see how to scaffold instruction for a student struggling with a specific concept or idea...This can help teachers by giving them ideas to use in their classroom.” For teachers who struggle in the moment to formulate effective questions, the AI tools offered valuable models and inspiration, helping to strengthen their ability to respond adaptively and thoughtfully to students’ mathematical thinking.

**Table 3.** Example Participants' Script Informed by MagicSchool.ai's Custom Chatbot Tool (Example 1)

Prompt Submitted to the Custom Chatbot Tool	Received AI Output	Participant's Script Informed by the AI Output
<p>You are a teacher who helps a kindergarten student solve the following problem: During your trip to the apple orchard, you see two different apple baskets. One basket is shaped like a circle, and the other is shaped like a square. Can you tell your teacher one way the circle basket is different from the square basket?</p> <p>Can you tell your teacher one way the circle basket is different from the square basket?</p>	<p>Here is a script of guiding questions to support the student:</p> <ol style="list-style-type: none"> <li><b>Start with Observation:</b> Can you tell me what you see when you look at the circle basket? What does it look like? Now, what about the square basket? Can you describe what it looks like?</li> <li><b>Encourage Comparison:</b> How many sides does the square basket have? Can you count them? What about the circle basket? Does it have sides? How many?</li> <li><b>Explore Shapes:</b> What do we call the shape of the circle basket? Can you say it out loud? And what is the name of the shape of the square basket?</li> <li><b>Discuss Size and Space:</b> If we wanted to put apples in each basket, do you think one basket could hold more apples than the other? Why do you think that? Which basket do you think is bigger or smaller? How can we tell?</li> <li><b>Encourage Conclusion:</b> Based on what we have talked about, can you tell me one way the circle basket is different from the square basket? How does knowing the shapes help us understand the baskets better?</li> <li><b>Build Confidence:</b> Great job thinking about the shapes! Remember, it is okay to make mistakes as we learn. What is important is that you are trying to understand. You are doing an excellent job explaining your thoughts! Keep it up!</li> </ol> <p>By using these questions, we can help the student articulate their thoughts and build confidence in their understanding of shapes and comparisons.</p>	<p><b>Setting:</b> A kindergarten student struggles to solve the following problem: During your trip to the apple orchard, you see two different apple baskets. One basket is shaped like a circle, and the other is shaped like a square. Can you tell your teacher one way the circle basket is different from the square basket?</p> <p><b>Script:</b></p> <p><b>Student:</b> This is too hard. I do not know anything about circles or squares!</p> <p><b>Teacher:</b> I am sure you know a lot about these shapes. Can you tell me what the circle basket looks like or what it reminds you of? (Start with Observation)</p> <p><b>Student:</b> The circle basket looks like a pizza.</p> <p><b>Teacher:</b> Yes! It does! Now, what about the square basket? Can you tell me what it looks like or what it reminds you of? (Start with Observation)</p> <p><b>Student:</b> The square basket looks like one side of a dice!</p> <p><b>Teacher:</b> You are right! Now, how many straight sides does a dice, or a square, have? (Encourage Comparison)</p> <p><b>Student:</b> It has four sides.</p> <p><b>Teacher:</b> What about a pizza, or a circle? How many straight sides? (Encourage Comparison)</p> <p><b>Student:</b> None...it is round and does not have straight sides.</p> <p><b>Teacher:</b> Ahhh...I see. Now that we know what we know about the sides of these shapes, do you think you can tell me how the square basket and the circle basket are different? (Encourage Conclusion)</p> <p><b>Student:</b> The square basket has four sides, like a dice, but the circle basket has no sides, like a pizza!</p> <p><b>Teacher:</b> You got it! I love how you used what you know about shapes to solve this tricky problem. You can do hard things! (Build Confidence)</p>

Table 4. Example Participants' Script Informed by MagicSchool.ai's Custom Chatbot Tool (Example 2)

Prompt Submitted to the Custom Chatbot Tool	Received AI Output	Participant's Script Informed by the AI Output
<p>You are a teacher who helps a 3rd student solve the following problem: Coach Maria is organizing a soccer tournament. In the first round, there are 3 teams. For each new round, the number of teams doubles. How many teams will there be in the fourth round of the tournament? The student is struggling to begin solving the problem. Record questions in terms of a script that can be asked to guide the student in solving the problem. How can you support the student in building confidence in their mathematical thinking?</p>	<p>To help the student think through the problem, we can use a script of guiding questions.</p> <p><b>1. Understanding the Problem:</b> Can you tell me what the problem is asking us to find? How many teams do we have in the first round?</p> <p><b>2. Identifying Patterns:</b> What happens to the number of teams in each new round? Can you describe that? If we start with three teams in the first round, how many teams do we have in the second round? Can you show me how you got that number?</p> <p><b>3. Continuing the Pattern:</b> Now that we have the second round, how many teams will be in the third round? What do you think we should do to find that? After finding the third round, how would you find the number of teams in the fourth round?</p> <p><b>4. Calculating the Final Answer:</b> Can you try to calculate the number of teams in the fourth round by using what you found in the previous rounds? What is the final answer for the number of teams in the fourth round?</p> <p><b>5. Reflecting on the Process:</b> How do you feel about solving this problem? Was there anything that helped you understand better? What strategy do you think you could use next time for a similar problem?</p> <p>By asking these questions, we encourage students to think critically and build their confidence as they work through the problem step-by-step.</p>	<p><b>Setting:</b> A 3rd-grade student is asked to solve the following problem: Coach Maria is organizing a soccer tournament. In the first round, there are 3 teams. For each new round, the number of teams doubles. How many teams will there be in the fourth round of the tournament?</p> <p><b>Script:</b></p> <p><b>Student:</b> I have no idea how to solve this problem. I do not understand what it is asking me to do.</p> <p><b>Teacher:</b> Okay, let us start by visualizing what is happening in the problem. I am going to read the problem to you, and then I want you to tell me what you are picturing in your mind when I read the problem. The teacher reads the student the problem.</p> <p><b>Teacher:</b> Okay, now what are you seeing in your mind?</p> <p><b>Student:</b> I see there are going to be some teams playing soccer, and I think there might be more and more teams that will play.</p> <p><b>Teacher:</b> Excellent. I had a similar math movie in my mind. Let us look at what this question is asking us. Can you tell me what this question wants us to figure out? (Understanding the Problem)</p> <p><b>Student:</b> The question wants us to figure out how many teams there will be in the 4th round.</p> <p><b>Teacher:</b> You are correct. Let us look at Round 1. Does the question tell us how many soccer teams are going to be playing in Round 1?</p> <p><b>Student:</b> Yes, three teams will be playing in the first round.</p> <p><b>Teacher:</b> Perfect. I want you to use the counters and show me three teams playing in the first round. (Identifying Patterns)</p> <p><b>Student:</b> Okay, I moved three counters over to show the three teams. But what does it mean if the teams double in the second round?</p> <p><b>Teacher:</b> I want you to think about what we have learned about multiplication. Doubling is a term used in adding and multiplying. Doubling means to add the same number twice. So, if our number is 3, can you show me with the counters what it would look like to double three if we are adding the 3 twice? (Continuing the Pattern)</p> <p><b>Student:</b> So, I would have six counters to represent Round 2.</p> <p><b>Teacher:</b> You are right; I want you to keep doubling the teams until we get to Round 4. Use the counters to help you see the doubling pattern. (Calculating the Final Answer)</p> <p><b>Student:</b> Continues to use the counters to double until the 4th round. I have 24 counters, and we are in the 4th round. So, there will be 24 teams playing in the 4th round.</p> <p><b>Teacher:</b> Excellent! Can you tell me about the strategy that we used to help solve this problem? Do you have a better understanding of how to solve these problems? (Reflecting on the Process)</p>

## 4.2 Improved Questioning Types and Sequencing

Another theme addressed the consideration for exploring varied questioning styles, including direct vs. open-ended questions. Several participants observed that while their own questions tended to be more exploratory, the Custom Chatbot's output posed more precise, outcome-oriented questions. For instance, one participant observed, "AI's questions were a bit more direct, and I tried to make my questions a bit more open-ended." While there is a benefit to AI's questions being more concise, the questions sometimes prompted a procedural focus, which participants criticized. Such participants preferred their open-ended or exploratory questions to promote a deeper conceptual understanding. Thus, tension was observed between the teacher's desire to encourage inquiry and student thinking versus the AI's efficiency in guiding students to an answer. Recognizing this difference led some teachers to question their strategies, wondering whether they should "be a bit more direct" depending on the student or context. However, such questions contradict strategies that promote productive struggle in mathematics. Instead, questions should support students in grappling with concepts, persisting through challenges, and reasoning through problems without being told what to do next (Hiebert & Grouws, 2007).

Furthermore, the participants critiqued the coherence of the questions with respect to sequencing and logic. The Custom Chatbot's output tended to follow a clear, logical sequence, often in a way that was more structured than the participants' own. For instance, one participant admitted, "AI's questioning was very step-by-step and had a clear pathway to the solution. I feel like my questions were not in the same logical order." This reflection speaks to the AI's strength in organizing questions that gradually build understanding and connect each step back to the central problem. Another participant observed that the Custom Chatbot's output asked questions following a dynamic flow that supported ongoing student thinking. Teachers saw value in this organization, as it offered a model for structuring their questioning more effectively to guide students more intentionally through problem-solving processes. However, it is important to note that some participants expressed concerns about AI output that may have compromised the cognitive demand of the best by over-scaffolding. Thus, AI output must be reviewed through a critical lens and not taken at face value.

## 4.3 Broadening Exploration of Diverse Strategies and Opportunities for Personalization

While many teachers appreciated the questions produced by the Custom Chatbot tool, several emphasized the need to tailor questions to their specific classroom contexts and students' needs. Some preferred their original questions because they incorporated concrete tools or strategies, like manipulatives. One teacher reflected, "I still stand by the questions I asked because I feel they are more beneficial to helping my students solve the problem." Another added, "The questions the tool posed were a little bit more generic to simply solve the problem...the AI tool's questions did not showcase the use of manipulatives or descriptions of visual models, whereas some of my questions did." Likewise, the participant acknowledged similar questions to the Custom Chatbot's output but concluded, "I liked the rest of my questions more than the ones [AI] produced...because I feel that it is important to incorporate manipulatives." This observation is also noted in Table 4, with the second example highlighting manipulatives (e.g., counters), despite the Custom Chatbot's output not making this suggestion. However, many participants appreciated how the Custom Chatbot's output prompted them to make connections related to their applications. One participant shared:

AI can develop well-rounded questions for the teacher to use. It can also show what kind of questions we can ask so that we do not give away too much of the answer when asking the question. I really liked how it developed multiple problems along the same lines. That

way, if [students] struggle with the first and need guidance from me, I can give them the second problem that is similar to try and complete it by themselves.

These reflections highlight that AI-generated content, while strong in structure and clarity, can overlook the nuances of individualized classroom interactions, particularly when teachers draw on prior knowledge of students' behaviors, preferences, or instructional tools.

#### **4.4 Enhancing Self-Reflection in Facilitating Productive Mathematical Discussions**

When reviewing the Custom Chatbot's output, teachers frequently noticed AI's inclusion of reflective questions (e.g., "How do you feel about solving this problem?"), which many had not originally considered. One participant noted, "AI provided a reflection/connection section that gauged the student's feelings about solving the problem. This would be beneficial to include." Others echoed this sentiment, with one saying, "At the end, I would add a question about how they feel now, and if they feel like they could solve the problem by themselves." Another participant admitted, "I did not think to ask questions that allowed students to reflect after working through the problem," but saw the benefit of these questions for "assessing the confidence level of students, which encourages perseverance in problem-solving." Participants agreed that these prompts could help gauge students' confidence, encourage perseverance, and offer valuable formative insights, leading several to plan to incorporate similar questions into their practice.

Furthermore, several participants reported that comparing their questions with AI-generated ones prompted them to reconsider how much they were guiding students versus fostering independent reasoning. Multiple participants described how the comparison encouraged them to re-evaluate their questioning strategies and consider revisions. One teacher reflected, "AI's output made me rethink the questions I asked." This process encouraged teachers to re-evaluate the intent, timing, and depth of their questions, leading some to add opportunities for student reflection and deeper thinking. For example, after reviewing the AI's approach, one teacher recognized the need to include questions that "allow students to reflect after working through the problem," something that had not been previously considered. This introspective process was beneficial in helping teachers expand their toolkit, reconsider their assumptions, and become more deliberate in engaging students in mathematical thinking. Thus, the Custom Chatbot functioned as a professional development tool, helping teachers refine their questioning strategies (e.g., type, sequence, depth) to facilitate productive mathematical discussions.

### **5 Discussion and Implications**

Findings from this study suggest that integrating AI into teacher preparation and professional development holds promise for deepening teachers' facilitation of problem-solving and questioning practices. Tasks such as scripting teacher-student dialogue provided a structured way for teachers to experiment with AI assistance, anticipate student thinking, and plan purposeful questions to support productive struggle. In this way, AI functioned as a tool to support professional noticing, allowing teachers to attend to students' mathematical strategies, interpret the reasoning behind those strategies, and make informed instructional decisions in response (Jacobs et al., 2010).

Moreover, the opportunities for reflection encouraged teachers to examine how their questioning and scaffolding choices shape students' reasoning (Tunjera & Chigona, 2023). Participants reported that AI-generated prompts helped them "rethink [their] thinking" or recognize when they might be "leading [students] too much." These reflections illustrate how AI can serve as a reflective lens, prompting teachers to critically consider the balance between guiding student thinking and allowing

for productive struggle. Productive struggle frameworks (Hiebert & Grouws, 2007; Warshawer, 2015b) emphasize the importance of maintaining cognitive demand (without over-scaffolding) and fostering student agency. In this study, AI scaffolds helped teachers reflect on when their supports either enabled or inadvertently limited these opportunities. At the same time, teachers noted limitations in AI output, including prompts that were overly generic and insufficiently contextualized to students' lived experiences, prior knowledge, and interests. Some participants also highlighted gaps in AI suggestions, such as the lack of visual representations to accompany solution strategies.

These benefits and limitations illuminate the need for teachers to use AI critically and contextually, treating it as a reflective mirror rather than a replacement for professional judgment. Thus, AI tools can help preservice and in-service teachers evaluate the structure, purpose, and progression of their questioning strategies (Pesce & Blanco, 2024), supporting professional noticing in action. Prompting teachers to consider how their questions support conceptual understanding, strategic reasoning, and perseverance aligns with the broader instructional goal of fostering mathematically proficient, independent thinkers.

To build on these insights, teacher education programs and professional development should offer structured opportunities for teachers to analyze, compare, and adapt both their own and AI-generated questions. In methods courses, for example, preservice and in-service teachers could design questions for a mathematical task, use AI tools like MagicSchool.ai to generate alternative prompts, and reflect on how each set of questions supports or constrains productive struggle, conceptual understanding, and student agency. Integrating AI into these reflective assignments not only strengthens teachers' digital fluency (ISTE, 2024) but also equips them to critically leverage emerging technologies while remaining grounded in sound pedagogical practices. Similarly, professional development workshops for practicing teachers can incorporate authentic classroom examples, fostering collaborative refinement of questioning strategies through side-by-side "AI versus educator" comparisons.

While these approaches show considerable promise, several limitations and equity considerations warrant attention. AI-generated prompts may unintentionally reproduce biases or fail to reflect the diverse experiences, backgrounds, and interests of all students, potentially privileging certain ways of thinking or learning (Akgunm & Greenhow, 2022; Holmes et al., 2019). Teachers must therefore critically evaluate AI output to ensure inclusivity, culturally responsive practices, and equitable opportunities for all students to engage meaningfully in learning (Grab, 2025). In addition, responsible AI use requires attention to ethical considerations, including transparency in instructional decisions, protection of student data, and preservation of teacher agency in guiding learning (Holmes et al., 2022).

Future research should examine the longitudinal impact of AI-supported reflection on teaching practice. For example, studies could explore how repeated engagement with AI prompts shapes teachers' classroom enactment, questioning strategies, and ability to facilitate productive struggle over time. Such research could also investigate how reflective AI practices influence teachers' attention to diverse learners, sustain high cognitive demand, and support equitable learning environments across different educational contexts. Although this study focused on elementary mathematics and MagicSchool.ai, the targeted school level and AI tool are transferable: similar tasks using different AI tools could be adapted for secondary settings, other content areas, and interdisciplinary learning experiences, expanding the potential reach and impact of AI-supported teacher reflection.

## 6 Conclusion

As AI tools become more widely accessible in educational settings, their potential as a reflective partner and instructional support, rather than a replacement for teacher judgment, must be emphasized (Holmes et al., 2019). The real power lies not in outsourcing instructional decisions to AI but in using

it to reveal and refine the thinking behind our teaching moves. When integrated with evidence-based practices, such as fostering productive struggle in mathematics, AI can help teachers anticipate students' thinking, improve question sequencing, and broaden the types of discourse brought to the classroom. Embedding AI-supported tasks into teacher preparation and professional development ensures that technology is used thoughtfully—not merely to save time, but to strengthen pedagogical practice and elevate instructional quality. Ultimately, these approaches support deeper student learning, promote agency and perseverance, and cultivate more reflective, inquiry-driven mathematics teaching.

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## Appendix A

### Task 3: Explore AI Tools as a Student Learner and Tutor

For this task, we will explore AI tools through the lens of a student and a teacher/tutor. To complete the parts of the task, we will use different AI tools from MagicSchool.ai. You will need to document how you use the AI tools, including what prompts you provide and what AI output is provided. It can be helpful to copy and paste your prompts into this file before you ask for the AI's output. The same applies to AI's output to guide your responses.

#### 6.2 Part 4

1. Create a problem using the Math Story Word Problem tool that you might ask a student to engage with. Use the same grade level and standard explored in Part 1. Select a story topic that your current/future students might be interested in to help you create the problem.

Grade level:

Math Standard:

Story Topic:

Number of Questions: Enter 3 or 5

2. After entering the information, click generate and review the AI's output. Copy the output below. You should see approximately three or five Math Story Problems.
3. Select one of the Math Story Word Problems. Highlight the problem above that you will explore. What are your thoughts on the Math Story Word Problems provided? Do you think the selected problem will interest your students and/or meet their learning needs? Why or why not? If not, how could you modify the problem to make it more meaningful and relevant to your students?
4. Independently, solve the problem you selected from AI's output. Be sure to record your work and problem-solving strategy. (You may wish to insert a picture of your solution strategy.)

#### 6.3 Part 5

1. Explore the Multiple Explanations tool to learn about other solution strategies associated with your solution in Part 4. Enter the grade level and the word problem for the concept being taught. Record your input below:

Grade level:

Concept Being Taught (copy the selected AI word problem):

2. After entering the information, click generate and review the AI's output. Copy the AI's output below:
3. Compare the AI's provided strategy to how you solved the problem. Did you use the same solution strategy? If so, what new information did you learn? If not, how did the different solution strategies provide you with new information about the problem?
4. Part of the AI's output provides information about related examples and analogies.
  - (a) How might a teacher use this information to scaffold the problem for students struggling with the problem?
  - (b) How might a teacher use this information to prompt enrichment and further mathematical exploration?

## 6.4 Part 6

1. Using the same Math Story Word Problem created by AI, pretend a student is trying to solve the problem. The student takes one look at the problem and shuts down. The student informs you that they cannot solve the problem. What questions might you ask the student to help them solve the problem? List at least five questions you could ask.
2. Now, use MagicSchool.ai's Custom Chatbot tool to inform your script. Enter the problem along with your role as a teacher who helps a student solve the problem. Be sure to include information about the student who is struggling to begin solving the problem. Record the questions you plan to ask in terms of a script that can be asked to guide the student in solving the problem. How can you support the student in building confidence in their mathematical thinking?
3. After entering the information, click generate and review the AI's output. Copy the AI's output below:
4. How does the AI's output compare to your thinking? What similarities do you notice? What differences exist? How might AI-generated questions help or change what you do in the classroom?

## Appendix B

### Coding Chart with Descriptions

Codes	Descriptions
Scaffolding	Questions provided scaffolded problem-solving strategies to support student understanding.
Question Types	Observed direct vs. open-ended style questions; appreciation for direct and efficient phrasing.
Sequencing and Logic	Questions followed a linear, structured order, encouraging systematic problem-solving to guide a solution.
Personalization and Context	Questions incorporating manipulatives and aligning with students' prior knowledge and classroom norms.
Reflective Practice	Questions encouraged student reflection or emotional check-ins, prompting teachers to rethink their own questioning.
Self-Reflection and Growth	Questions prompting introspection about how to improve questioning strategies and better support productive struggle.