Exploring the Potential of AI for Personalized Mathematics Education

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***Abstract*—This study explores the potential of artificial intelligence (AI) in personalized mathematics education for secondary and upper secondary levels (years 7-12) in Sweden. By examining teachers' current practices, their perception of AI, and thoughts about AI's potential in the classroom through a survey together with research on current AI models, this paper investigates the possibilities of this incorporation. Preliminary findings highlight that there is an interest in AI as an educational tool. Teachers primarily believe in AI's ability to tailor practice content to individual student levels as well as providing instant feedback and targeted tips for mathematical skill development. However, concerns persist about the flexibility of recent AI models in addressing diverse student needs and understanding them on a personal level, including their background and emotional needs. Therefore, this study concluded that there is an interest and belief from teachers that AI can be of assistance in the classroom, but there are still question marks around the exact competence of the current, popular AI models when it comes to flexibility in working with students. These insights contribute to the conversation on AI's role in classrooms, particularly in enriching personalized learning for mathematics students.**

***Index Terms*—education, AI, mathematics, learning materials, instant feedback, personalized material**

I. Introduction

As society evolves, and technology becomes increasingly advanced, educational requirements also progress accordingly. Consequently, the volume of knowledge that students must absorb has grown, and at times, become more complex.

The traditional education system [1] relies on a standardized curriculum designed to cater to the majority. However, the introduction of personalized learning paths [1] has shed light on the possibility of more effective methods. The recent trend toward personalized learning materials tailored to individual students has demonstrated significant advantages in terms of both academic outcomes and student motivation [2, 3].

In today's dynamic educational landscape, it has become increasingly clear that one size does not fit all, especially when it comes to educational content that aims to foster higher-order thinking, mastery of complex knowledge, and the development of students' skills [4]. Students have different learning styles, paces, and preferences, which means that traditional educational methods do not always meet the unique needs of students as effectively as they can [5]. As a result, the interest in using technology, including artificial intelligence (AI), in schools has grown, aiming to enable a broader range of educational materials and learning methods for students more seamlessly [4].

AI-powered tools for education (AIEd) have been explored and developed for some time now. As shown by the summary of AIEd studies in Chen et al. [6], there is a wide variety of AI techniques and application scenarios for AIEd in the current year. This revolution may be particularly relevant in mathematics education, where AI has the potential to not only deliver mathematical concepts and methods but also to enhance higher-order thinking skills such as critical thinking, problem-solving, and creative thinking [7, 8].

Recent advancements in AI technologies have brought significant opportunities to improve teaching and learning [8], transforming how students engage with educational content. AI can act as an intelligent tutor, offering personalized support and feedback tailored to individual students, as well as guiding teachers in optimizing teaching strategies and content.

However, the implementation of personalization with AI, while promising, comes with its challenges. It requires dedicated resources, including technical infrastructure and extensive teacher training. In addition, ethical considerations regarding data privacy and algorithmic bias must be addressed to ensure that AI-powered education remains both effective and fair.

A. Objective

This study aims to investigate how AI can be applied in the classroom to create personalized educational content, evaluate students' performance, and offer real-time feedback in mathematics. Looking at current AI technology, focusing on its capabilities within the field of mathematics, this study will also include a survey with mathematics teachers to explore effective ways to integrate AI-driven customization into their teaching practices. The study will focus on secondary education (years 7-9) and upper secondary education (years 10-12) in Sweden.

II. Theory

The theory for this paper consists of an introduction to the concept of personalized learning and its differences from the traditional curriculum. Following this, AI is researched further, first with a focus on its current capabilities of creating learning content and then with a focus specifically on its current capacity in mathematics.

A. Personalized Learning

An individual learning path [9] is a personalized journey designed to help individuals achieve their long-term personal goals. This is done by tailoring their education and development to their unique learning styles and preferences, such as pace, subject interests, individual strategies, etc. Furthermore, learning activities are often meaningful and relevant to the learner, driven by their interests, and often self-initiated.

B. Comparing Traditional Curriculum to Personalized Learning

The traditional classroom curriculum typically refers to a teacher-centered delivery of instructions to a classroom of learners. Topics discussed are generally from a course plan that is largely common between multiple local schools. Progress and achievements are often measured by testing the student's memorization of knowledge and skill comprehension. The primary procedure consists of oral instruction, reading, and reciting facts [1].

Back in the 2010s, massive open online courses (MOOCs) [10, 11] were already being recognized as a challenger to traditional education, offering advantages such as cost efficiency, accessibility, and competency-based education. MOOCs [12] are accessible online courses designed to offer high-quality education globally, irrespective of location or financial constraints. They are usually provided by leading institutions, covering diverse topics, and allowing self-paced learning. MOOCs also often offer a variety of interactive features, such as discussion forums and video lectures, to enhance the learning experience.

C. AI-Generated Learning Content

The use of AI in education (AIEd) has become more and more established over the years, both as AI models specifically designed for educational purposes, as well as the incorporation of AI into existing educational tools. A notable example of this is Quizlet, a widely used app for studying and repetition-based learning. In recent times, Quizlet introduced their new AI tutor, *QChat*, built with OpenAI's ChatGPT [13, 14]. This feature builds on top of Quizlet's past six years of using AI to enhance student learning [15].

There are many more influential AIEd implementations [6]. AI technologies can analyze students' learning process, including interaction content, learning behaviors, test results, and learning perceptions, to provide instant support or feedback to individual students. It can also assist teachers in improving teaching content and strategies [16].

D. AI in Mathematics Education (AIME)

In the context of mathematics education, AI technologies have been harnessed in prior studies to emulate the role of teachers [17, 18, 19]. These studies involve AI systems that simulate teachers' actions, offering insights into diagnosing students' learning challenges, delivering personalized learning materials and pathways, as well as providing suggestions or guidance to individual students in mathematics courses.

Critical thinking, problem-solving, and creative thinking represent essential abilities within mathematics [20]. As a result, it becomes intriguing to investigate the potential of AI in facilitating a more effective development of these skills among students. There are already multiple successful stories in the world of AIME implementations assisting with this.

An example brought up in Cunska [21] is the platform "Mental Math" developed by the Estonian company Miksike. This platform has been successfully applied for several years. It has significantly enhanced fundamental mathematical skills by offering a diverse range of activities that evaluate and develop the mathematical knowledge of the students. They benefit from this platform by engaging in training, and global competitions, which has led to the progressive development of their resilience and mathematical proficiency.

Another case highlighted by Cunska is the Mathematical Adaptive Platform (PAM), an online adaptive learning solution developed in Uruguay. PAM aligns with the national mathematics curriculum and offers personalized feedback tailored to individual students' skill levels. It supports students with over 25,000 distinct tasks and provides 2,800 feedback responses to help students understand the solutions to each task.

E. ChatGPT, GPT-4, and Recent AI Advancements

Regarding recent advancements in AI, one AI model that has stood out recently is OpenAI's chatbot, ChatGPT [22]. ChatGPT [23] utilizes the language model GPT (Generative Pre-trained Transformer), developed by OpenAI. It is trained to follow instructions in a prompt and provide a detailed response. It can do things such as debug code, write code, summarize content, explain concepts and more [24]. Currently, in December 2023, users can use ChatGPT powered by either GPT-3.5 or their newer GPT model, GPT 4, which shows improvement in a majority of use areas [25].

Shifting the focus back to mathematics, recent advancements of the GPT-4 language model show an improvement over the GPT-3.5 model regarding mathematics capabilities. To test its capabilities, and the performance difference between the models, OpenAI ran tests, presented in their technical report in March 2023 [25], to evaluate the GPT-4 model on a variety of exams originally designed for humans.

To assess both its capabilities and the performance difference across models, OpenAI conducted tests outlined in their technical report from March 2023 [25]. These tests aimed to evaluate the GPT-4 model using a variety of exams originally designed for humans, one of which was the SAT math exam. The SAT math exam [26] measures the student's ability to perform math procedures accurately and efficiently, assesses their understanding of key concepts and connections between them, and tests their application of math skills to solve real-world problems.

The results from the simulated SAT math exam were 700/800 (top 89^{th} percentile) for the GPT-4 model and 590/800 (top 70^{th} percentile) for GPT-3.5. This shows that both GPT models have the capability of performing in multiple

aspects of mathematics and that the models are becoming more capable with time.

Regarding the limitations of the GPT language models, one major concern is that it is still not fully reliable. As described on the OpenAI website, it still ”hallucinates” facts and makes reasoning errors now and then. However, GPT-4 shows improvements in this aspect, with a score of around 74%, compared to GPT-3.5 with a score of around 59%, on internal adversarial factuality eval. Eval is OpenAI's open-source software framework for running benchmarks for evaluating language models similar to GPT-4. In this evaluation, an accuracy of 100% would equate to the human ideal responses for all questions in the eval [25].

III. Methods

For this study, a mixed-methods approach was employed to comprehensively investigate the integration of AI-driven customization in mathematics education and compare it to teachers' thoughts about AI's potential and challenges in the classroom.

A. Survey

A structured survey questionnaire was conducted for educators to gather quantitative data on their experiences and perceptions of AI in math education. The participants consisted of math teachers from secondary school and upper secondary school.

The survey consisted of 17 questions, most of which were either multiple-choice or yes/no questions. The questions were divided into 6 categories; Introductory questions (demographic questions), generally about teaching, current digital tools and technology use, current AI-powered digital tools and technology use, benefits and concerns with AI, and current personal education and knowledge of AI. All instructions and questions were in Swedish when conducting the survey and later translated into English for data analysis and results presentation.

Before sending out the survey, pilot testing was done to identify any potential problems with the questions or flow of the survey. This was done with two candidates, both from the target group. From this, some issues were found with the initial flow of the survey. Another comment that was brought up during the pilot testing was that it was good with general, multiple-answer questions for this particular topic and target group. There was also a wish to make it possible for the participants to be more specific about their own, current knowledge about AI. Thus, that was changed from simply being a yes or no question, to having a follow-up question with more options.

B. Data Collection & Data Analysis

A comprehensive review of existing AI technology, AI in education, personalized learning, and AI's capabilities in mathematics served as a foundational resource for this study. This data was analyzed with the data collected from the surveys to conclude the possibilities of using AI to create customized content and assist in mathematics education.

For each of the multiple-answer questions, there was also an *Other* option, where the respondent could add an option outside of the pre-defined ones. To analyze the answers collected from these options, as well as those collected from open-ended text questions, a thematic analysis [27] was used by reading through the data from these options and looking for common patterns.

C. Limitations

This research acknowledged certain limitations, including potential selection bias among survey and interview participants. Additionally, the study's findings may not apply to all educational settings, given the focus on a specific subject. Limitations to consider with this survey was the lack of possibility for the respondents to express a direct non-interest in AI in the classroom. The multiple-answer questions were all obligatory questions, where up to three answers could be selected. Therefore, questions about AI's potential might have a bias as at least one selected option was required. The use of an ”other” option here might have helped with this to an extent.

IV. Results

This section presents a comprehensive overview of the survey findings from this study, highlighting the perspectives of mathematics teachers regarding the integration of AI in the classroom. The data is presented through a combination of visual representations, such as cluster bar diagrams, and textual summaries.

A. Respondent Demographics

There were a total of 60 mathematics teachers that participated in the survey, of which 33 were women, 26 were men, and 1 preferred not to disclose their gender. 28 respondents were teaching mathematics at the secondary education level (years 7-9) and 32 were teaching at the upper secondary education level (years 10-12). The age distribution of the respondents can be seen in Figure 1, and their experience teaching mathematics at the secondary or upper secondary can be seen in Figure 2, with a majority having more than 20 years of experience.

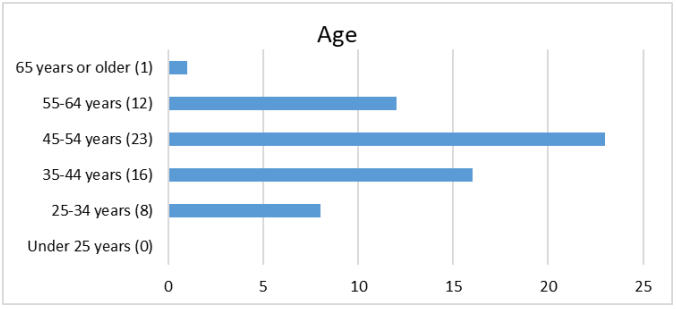

Fig. 1. Participant ages

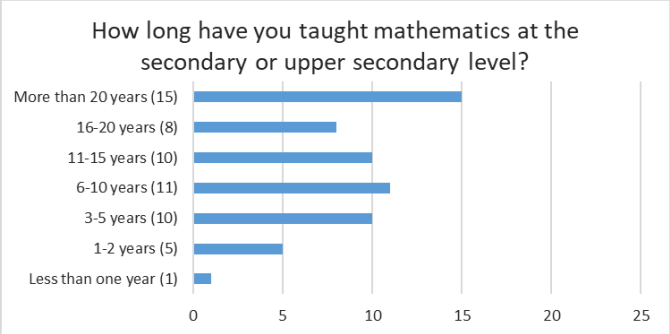

Fig. 2. Participants' math teaching experience

B. Findings

The survey included questions regarding teachers' current methods and digital tool usage in the classroom. A multiple-answer question asking about specific challenges teachers face in conducting certain aspects of mathematics education for the entire class. There were also more open-ended, text questions, about teachers' methods of addressing individualized tasks, and whether they currently utilize any digital tools, or perhaps AI-powered digital tools, for their teaching.

The results from the question regarding challenging tasks to do in full classes can be seen in Figure 3. The answers from the "other" option in this question brought up things such as balancing diverse knowledge levels within a larger group at the same time. Providing different levels of practice material to meet each student's level is a challenging task. One participant wrote here *"The biggest challenge is to keep up with everyone at such different levels. The problem is not how I should do it but how I'll manage to keep up."*.

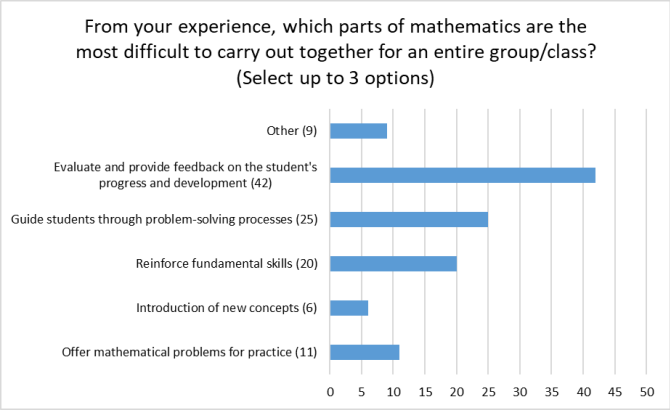

Fig. 3. Most difficult parts of mathematics to carry out for an entire class at once.

The answers regarding current methods or use of digital tools mentioned a variety of different digital tools. Visualization and geometry tools, notably Geogebra, were mentioned, emphasizing their utility in illustrating mathematical concepts. Interactive learning platforms such as Matteboken.se and Gleerup help with both theory and practical exercises. The use of assessment and progress-tracking tools like Kunskapsmatrisen was mentioned, providing a structured approach to evaluating and tailoring content based on individual student needs. Microsoft Office tools, including Excel, PowerPoint, and OneNote, were brought up for their versatility in supporting various aspects of mathematical instruction. Digital math games and apps like Blooket, Kahoot, and Quizlet as engaging resources for interactive and collaborative learning experiences.

For the questions asking about AI in current praxis, 12 respondents said that they know of AI-powered tools for mathematics education, however, only 3 respondents answered that they currently use any of these AI-powered tools in their teachings. One mentioned the use of Khan Academy, an online platform with courses and other tools to help educate students, and 2 respondents mentioned the use of ChatGPT to create practice problems and solution proposals.

one of the respondents mentioned that they use any AI-powered tools as of now, but some mentioned that they are unsure of whether their current digital tools utilize AI or not.

Regarding the educators' perspectives on the potential benefits of integrating AI into their mathematics instruction and the challenges they foresee in its implementation, the findings can be seen in Figure 4 for perceived advantages and Figure 5 for identified obstacles.

In the *Other* option for challenges with AI, participants expressed concerns about AI's limited capacity to comprehend the emotional needs of students facing challenges or seeking positive reinforcement. They highlighted the importance of understanding a student's background and individual circumstances. Another concern in a similar theme was the AI's lack of knowledge about the current skill level of the student, for example, if the AI proposes solutions using methods that have not been introduced yet, and/or are not part of the current course the student is in. The *Other* option for potential with AI consisted only of answers regarding the respondent not feeling like they knew enough about AI to answer the question.

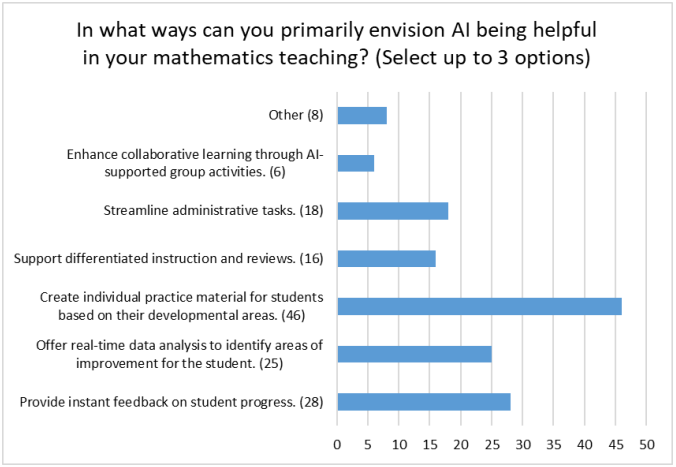

Fig. 4. Potential of AI in mathematics teaching according to teachers.

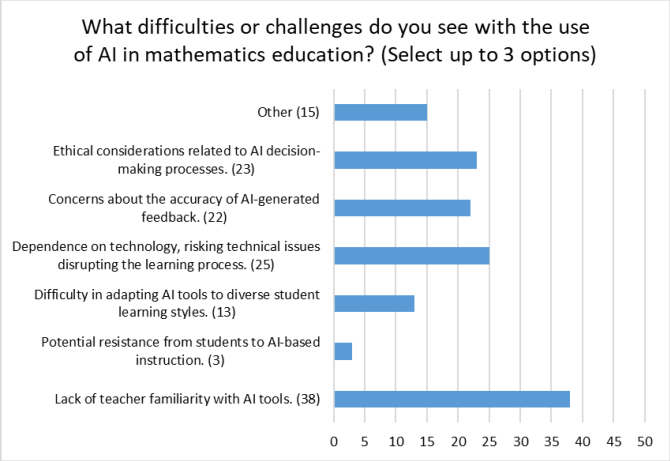

Fig. 5. Challenges of AI in mathematics teaching according to teachers.

The survey also included a question regarding whether the respondent feels like they have enough knowledge about AI to integrate AI tools into their mathematics teaching, with a follow-up question of what would be needed for them to feel more comfortable using AI. Most of the respondents answered no to the first question, and most thought that good solutions for this could be educational workshops, online courses, and also if more educators around them have tried it as shown in Figure 6.

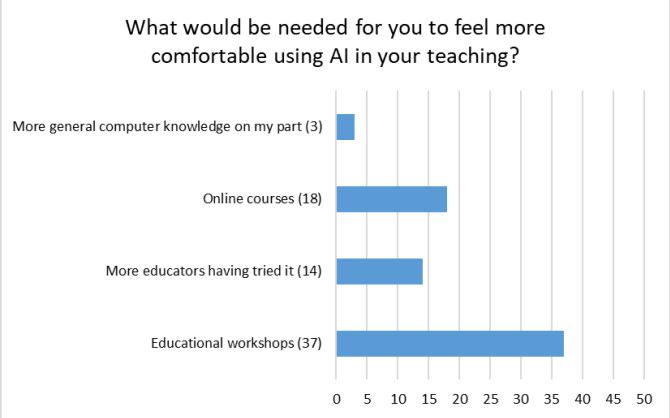

Fig. 6. What would be needed for teachers to feel more comfortable using AI in the classroom?

V. Discussion

When it comes to teachers' attitudes toward AI and thoughts around its potential within mathematics education, the results of the survey show that there are areas where a majority of the teachers believe that AI can have a place. This was especially emphasized when it came to areas such as creating individual practice material for students and providing instant feedback on student progress. These results also correlate with the teachers' experiences of which parts of mathematics are most difficult to carry out in an entire class at once as shown in Figure 3. That things such as evaluating and providing feedback on student's progress and development are things that require the most individual attention, which may be why many teachers feel like this could be an area where AI could be helpful.

Balancing diverse knowledge levels within a larger group was also a concern in the current state of maths education. Multiple respondents stressed the fact that for things such as being there for different students at different skill levels, it is more about not having time to be there to provide practice content and feedback, rather than not knowing how to do it. As shown by examples of AIME software mentioned in *AI in Mathematics Education (AIME)*, AI can help with creating practice material for students, and answering questions on math problems. With chatbots built on language models like ChatGPT, this becomes even more fluent, as students can also get continuous feedback on how they are doing. Especially with GPT-4 scoring in the top 89^{th} percentile in the SAT math exam [25], and efficiency being a key factor in this exam, it speaks for these generative AI models being able to assist the student with feedback on more efficient ways of solving math problems. This goes back to the challenge of being able to provide instant feedback for all students in the classroom. However, caution is still needed here for AI's lack of comprehension of the student's emotional needs when it comes to providing feedback and constructive criticism.

When it comes to the challenges of implementing AI in the classroom, multiple respondents mentioned concerns with the accuracy of AI such as ChatGPT. This concern is very valid, as seen by the results of the eval testing in the latest technical report for GPT-4 [25]. While showing promising results in terms of capabilities, inaccuracy is still to be expected, both with factual statements and with "hallucinations".

Another concern mentioned was how the AI may propose solutions using methods that the student has not yet had a chance to learn, due to course planning or other circumstances. Past implementations of more advanced tools in AIME, such as *Mental Math* and Mathematical Adaptive Platform (PAM) [21], have been focusing more on practice material that corresponds to specific courses, preparing for specific exams. Thus, it is hard to say exactly what the best approach is to tackle this concern when using more open-ended tools, such as language models and chatbots. Since mathematics as a field is so vast, laying out all the concepts that are relevant for the student's current course for the AI, or vice versa, seems like a tall task. Instead, this can be tied to the ongoing revolution of personalized learning and online courses challenging the traditional curriculum discussed in *Comparing Traditional Curriculum to Personalized Learning*. To allow for these more flexible systems to help students, the school system as it is right now might have to change in a way that can allow for a larger spectrum of possible pathways that the individual can take, to reach a universal goal [1].

While discussing the change toward a more personalized curriculum, one aspect that is being overshadowed in light of all the individual benefits [2], is group activities. When asked about the potential of AI as a tool in mathematics teachings,

only 6 respondents chose the option regarding enhancing group activities, as shown in Figure 4, which indicates that the request for AI-driven group activities is not large at the moment at least. This question, however, focused on the potential of AI more so than group activities in general.

A. Limitations

While the survey's 60 respondents offered a comprehensive overview of various perspectives in response to the main, multiple-answer questions, it remains insufficient to draw definitive conclusions regarding the general stance of mathematics teachers on AI in education. The demographic was also limited to teachers in Sweden, which was specified in the objective but is still something to keep in mind when interpreting the results.

Another limitation of the survey is that it did not require any personal identification, such as an email or phone number, allowing the possibility of multiple submissions by a single individual and potentially biasing the results.

In terms of the theoretical framework and the current state of AI, a more in-depth exploration of recent language models, including those challenging GPT-4 such as Claude 2[1] or Google Gemini[2], could have added depth to the discussion. This could have provided a more nuanced comparison between teachers' expectations of AI assistance and the current capabilities of AI in the educational context.

Before the incorporation of these generative AI language models, there could be a need for more research on the capabilities of the AI model for the specific subject. For example, OpenAI presents an overall score for the simulated exams taken by their GPT models, however, it is not specified how well the model performed in each aspect of the exam. Hence, there could still be differences in performance depending on the task, even though the overall score of the exam is high.

VI. Conclusion

The objective of this study was to explore how AI can be used to create personalized educational content, evaluate students' performance, and offer real-time feedback in mathematics. An associated survey was conducted to hear from teachers what they think about AI and its potential for assisting in the classroom. The findings show that:

- There is an interest and belief from teachers that AI can be of assistance in the classroom when it comes to mathematics education.
- The main belief is in AI's ability to create practice content tailored to the student's level, and its ability to provide instant feedback and tips for the students to further develop their mathematics skills.
- Both past studies around it, and past implementations of digital tools and AI-powered digital tools for math education purposes have shown effective for enhancing the student's learning process in maths.
- Recent advancements in AI, such as generative AI and natural language models, show an increasing capability of AI in mathematics that scores high on established exams such as the SAT maths exam.
- This speaks for AI's potential to assist students in their learning process and allow students to receive instant feedback on how they are doing.
- With these findings, there are still question marks around the exact competence of these recent AI models when it comes to flexibility when assisting students, as well as their lack of knowledge of the student as a person, their background, and their emotional needs.

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