NittanyEdu
AI & Education 1
CMPSC 442 Spring 2023
Research Report

Figure 1.

Note. phonlamaiphoto. Robot with empty blackboard [Image]. Adobe Stock. (https://stock.adobe.com/images/robot-with-empty-blackboard/278292820). CC BY 2.0.

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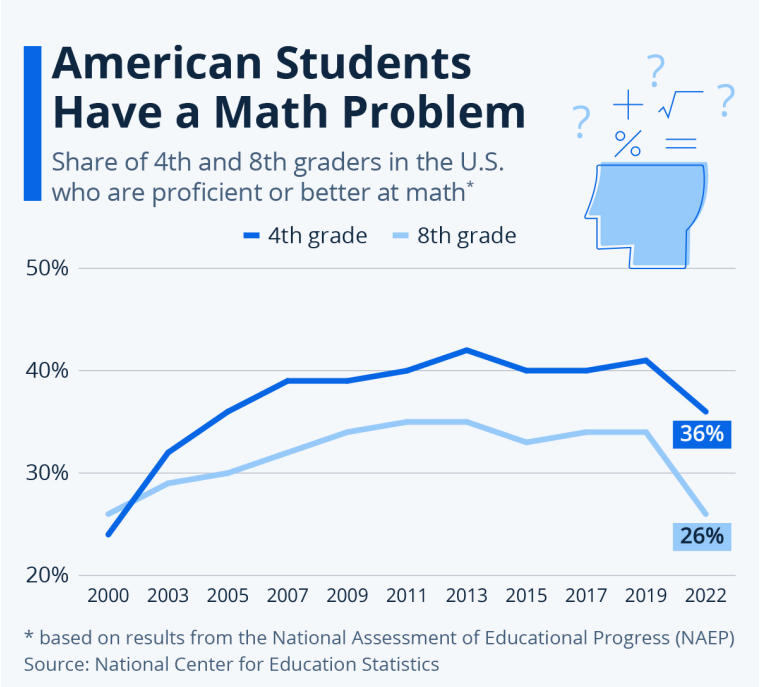
Introduction

In the last decade, the use of technology such as laptops and tablets in education has become increasingly prevalent. With the accessibility and emergence of new technologies, students are required to navigate computer systems while attempting to simultaneously learn new topics. During the COVID-19 pandemic, the transition to online learning also presented many problems for students of all ages. The main problem during this time is the lack of personalized education. Schools were forced into adopting a one-size-fits-all approach to teaching which failed to address the individual needs of students. If a student falls behind in any class, especially math, it can become incredibly overwhelming for them to make up for the missed topics. Furthermore, teachers are struggling to provide targeted support and feedback alongside their normal lectures. This can lead to boredom, disengagement, and most importantly low academic proficiency. Because of all of this, students are struggling more than ever to understand the concepts being taught to them, especially in mathematics. According to the National Assessment of Educational Progress (NAEP), studies have shown around 36% of 4th graders and 26% of 8th graders in the United States are proficient in math as shown in Figure 2.

Figure 2.



Note. From the *National Assessment of Educational Progress* by F. Richter, 2022.

Noticing the decline in proficiency, our team created MATHstermind. Our solution was created through rigorous research dealing with these main questions:

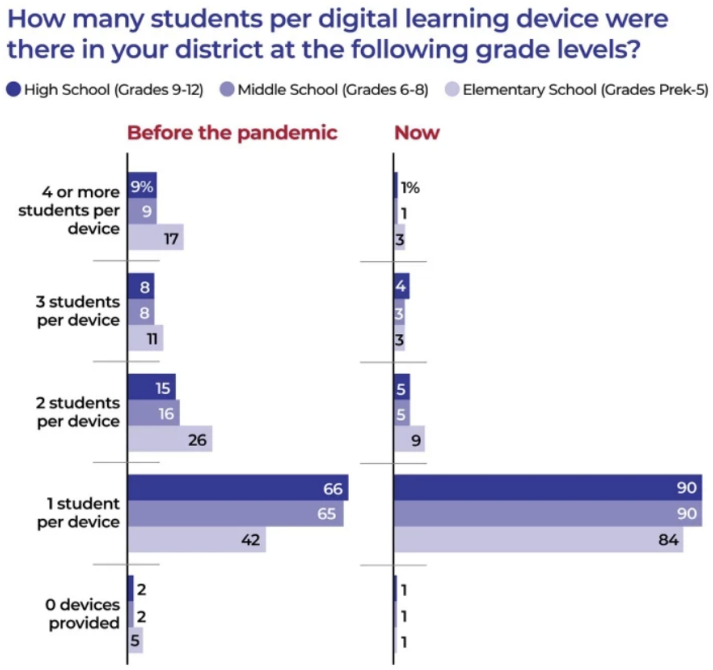
- How can we improve assignments to promote more focus and learning?
- What tools can be used to improve lessons and overall education?
- How can the typical problems of classroom environments, including lack of one-on-one time, be aided through the use of artificial intelligence?
- How will we determine proficiency of a subject?
- How will MATHstermind define the line between tutoring and just providing an answer?

Through our intensive review of research papers, articles, as well as acknowledging where research was not available, we believe that we have found a solution that answers these questions. To ensure personalization, our dataset is built through user experience with our AI system. Our team realized that other students' data is irrelevant to how our system should interact with the user, so each individual student will alter their own data to create a purely individual experience.

Solution

MATHstermind, the revolutionary Artificial Intelligence math tutor, seeks to change the landscape of mathematical education. With its intelligent tutoring system, MATHstermind provides personalized, adaptive, and interactive learning experiences to students of all ages and skill levels. This personalized approach ensures that students will never fall behind in their learning while staying engaged the entire time. Students today are spending more time than ever on computers and similar devices. With the increase in availability of technology for students in the past two years, creating an online solution allows for more access to tutors for all students. The availability has increased from around 40-60% at all grade levels having 1:1 technology access, to almost 90% at all grade levels, as shown in Figure 3 from Education Week.

Figure 3.

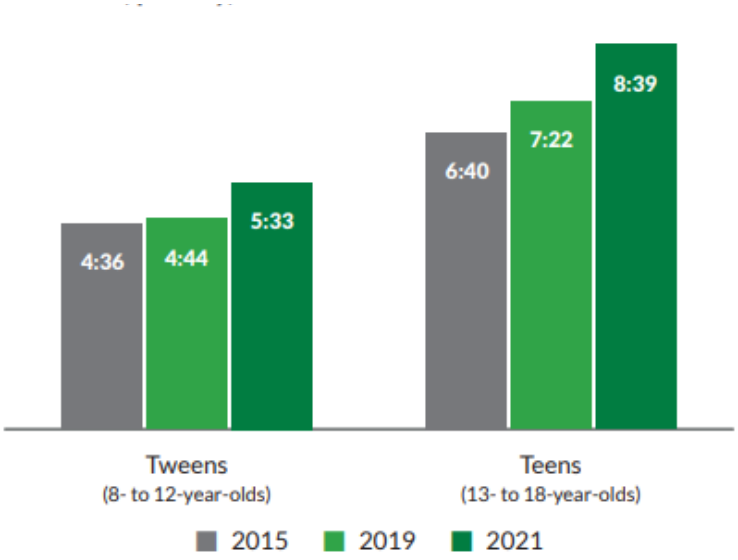


Note. From *Education Week* by Bushweller. 2022.

According to findings from the non-profit Common Sense Media, children from the ages of 8-12 are spending an average of 5 hours and 33 minutes per day of screen time, while ages 13-18 are spending an average of 8 hours and 39 minutes per day. These numbers are all increases from past years, as shown in Figure 4 from Common Sense Media. While this may be concerning to the average citizen, our team sees this as the perfect opportunity to ensure that education takes up a large portion of that time. Since children are already going to be looking at a screen, why not make sure that they learn something by the end of it?

Figure 4.

Total Entertainment screen among tweens and teens, per day, 2015 to 2021



Note. From *The Common Sense Census* (p.3) by Rideout et al. 2021. Copyright 2022 by Common Sense Media

MATHstermind is the key to making sure children are not wasting their screen time. Since they are unable to get the education that they need in school, when they are out of school they deserve to have time to catch up. One of the first problems that our team recognized is trying to get parents on board with having their children using technology to learn. Given the circumstances of growing technological use in everyday life, we feel that giving students an option to extend their learning while utilizing technology they will be using for the rest of their lives is extremely valuable. Since these students are gaining more access to devices outside of the classroom, their technological skills are growing at an exponential rate. These skills directly translate into how they will use MATHstermind. Kids will not only be mindlessly sitting on their computers watching videos or scrolling through photos, they will be using their computer skills to enhance their minds. In the same way, it helps children get more accustomed to using a computer, another invaluable skill that can help them in their educational careers. From a learning perspective, using a computer helps save time while also providing an environment equally as helpful as having an in-person tutor. Our system acts as a virtual tutor, giving personalized help to the students and providing encouragement to keep pushing through the difficulties.

Technical Aspect of Solution:

Our team's approach was to make a personalized tutor for students who want to improve on or need help with their foundation mathematical skills. We used the concepts of reinforced learning to be able to develop our system. The University of York in the United Kingdom defines reinforced learning as “a subset of machine learning that allows an AI-driven system (sometimes referred to as an agent) to learn through trial and error using feedback from its actions” (Diaz). To continue with their definition, the feedback from the agent’s actions has a positive or negative award attached to it. The agent’s goal is to be able to maximize its reward.

Within the scope of our code, we have an agent, who is the user or student, an environment which is the virtual math tutor where it will be asking the questions, the state is the specific area of the environment which the agent will be (this would be within one of the three different levels the agent could be in), an action which are the steps made by the agent (this would be the agent answering a question, and finally, with that action taken, there is reward that will be given to the agent. Each of these terms are fundamental parts to what makes a system a reinforced learning model.

Through this environment, this student will first be asked to take an initial quiz. This initial quiz is a baseline test that the user is required to take when they start the program. The information that is gathered from this baseline test is able to train the model. When we say we are training the model, we are understanding the strengths and weaknesses of the user’s ability with different numbers and operations. Each number and operation is assigned a specific weight that when ranked higher, will have a higher chance of appearing and vice versa. This implementation allows our environment to be set up such that it generates questions that will suit better for the student/agent when they start answering the questions.

For our AI implementation, our goal might be slightly different than others. With no true algorithm like Q Learning and temporal-difference that can find optimal policies, we took the influence from a game. The influence of our application’s policy came from an example from the University of York explaining older Atari games where the strategy is not always looking for the instant reward but the “maximum cumulative reward over the length of training.” (Diaz). This gave us the concept to create an algorithm that uses weights for the numbers and operators to generate questions like stated in the paragraph above. The agent will follow an iterative policy of selecting a level and attempting to get each of the ten questions right to be able to reach the goal

state. After each state, the agent will perform an action by stepping to the next question or state. By the end of each iteration or the last state, the model will have a better understanding of the student's successes and errors and create new problems to assist them. It is like the classic saying, "the more you practice, the better you get," and with basic math arithmetic or any other branch of math, it is the most common way to learn.

Ethical Considerations

As much as AI tries to help all students in the sphere of education, there must be discussion about the ethical issues that are connected with education and AI. Through much of the lectures and journals we have learned in class this semester, one of the things that we can take from this class is knowing that the best intentions for a new technology or AI system is not always the best as it could have conflicting issues. In the International Journal of Artificial Intelligence in Education Issue 32, we will focus on the findings in the article titled Ethics of AI in Education: Towards a Community-Wide Framework by Wayne Holmes.

The article introduces the ethical issues that surround education and AI. The first thing that is discussed in Wayne's findings is the general ethics of AI. Wayne states that main problem of ethics always comes down to data stating that "all of these efforts principally focus on data (involving issues such as informed consent, data privacy, and biased data sets) and how that data is analyzed (involving issues such as biased assumptions, transparency and statistical apophenia – finding patterns where no meaningful, causal patterns are present)." (Holmes). In class, we have read the works of Timnit Gebru such as Datasheet for Datasets that pushes for the use of datasheets for datasets to help, "encourage careful reflection on the process of creating, distributing, and maintaining a dataset, including any underlying assumptions, potential risks and harms, and implications of use." (Gebru, 2). We want to bring light and to talk about ethical issues in general in AI as it helps picture the big issue that is occurring in AI and the current solution currently happening. These issues and solutions tie closely to what is occurring in education as well. Wayne citates three different articles in their findings that they took time to summarize each but we will go a little bit further into each article. First we will discuss the findings in Isak Potgieter's "Privacy concerns in education data mining and learning analytics."

In Potgieter findings, he states a claim that closely aligns with what we introduced this section about and that is data. Potgieter suggests that educational data mining is “not the superconductor of truth that some of its proponents believe.” (Potgieter, 3). The reason behind this interpretation is due to the examples seen in machine learning algorithms having the lack of casual comprehension within big data. With these missing skills, Potgieter claims that people “should be hesitant to put complete faith in the efficacy of data-driven science.” (Potgieter, 3). The reason behind this thought process makes sense as we would be putting a lot of trust into tools that will be affecting the “foundational impact” of a “child’s formative years,” which could have some beneficial or detrimental impacts that are currently unknown (Potgieter, 3). Potgieter concludes his article stating that introducing AI tools into education cannot “be maintained and the transformative impact that it will have on the autonomy of learners is cause for concern.” (Potgieter, 5).

The article titled “Learning analytics: ethical issues and dilemmas” written by Sahron Slade and Paul Prinsloo goes into the “number of ethical challenges, including issues of the location and interpretation of data; informed consent, privacy and the de-identification of data; and the classification and management of data.” (Slade, 2). As for the location and interpretation of data, this goes into the potential problems of “digital data [being] fully representative of a particular student.” (Slade, 8). As these learning systems would be making assumptions based on a student that will be a part of a very large data set of other students that will not be personalized to itself but rather to others. In essence, comparing a student's results and learning with others is not the best approach and ethically not correct to do. As for the informed consent, privacy, and de-identification of data section, this section goes into details regarding ethics of tracking and analyzing student data. As students may not be totally willing to give their personal data to these learning systems and if so, it is important to make sure this data is kept private but enough for the system to be able to identify the user/student. The final section is the classification and management of data. This centers around the “need for a ‘comprehensive data-governance structure to address all the types of data used in various situations’ addressing the need to create ‘a data-classification system that sorts data into categories that identify the necessary level of protection’.” (Slade, 8). This section brings up the problem or issue that these algorithms will categorize patterns that “can result in keeping individuals prisoner to past choices.” (Slade, 10).

In the scope of education, an AI system could lock a student in one area even though they could be progressing well which can lead to unwanted assumptions about a students learning abilities.

With these problems, Slade and Prinsloo have researched a solution to fight against these ethical issues. Even though this framework is tended to higher education, it can still apply the same ways in lower education. Slade and Prinsloo set up a framework that would be needed for using learning analytics. The principals are set as followed: “learning analytics should function primarily as a moral practice,” students should give consent and give them access to collaborate in the data to adjust their development in learning, each student’s data has expiry date to allow the student’s data to evolve over time, understanding that student success is very complicated so it will not always move in a linear or exponential way, and being transparent with the data (Slade, 12). Given these principals, students and their parents can use learning tools that can help assist and shape them in the way that best fits them.

Within these research papers, there were different ways these authors stated their ethical concerns with education. To wrap up this section, let’s take a quick moment to recap the issues that were stated above and that our team found the most crucial. Privacy is a concern throughout all spheres of AI. With education, student data such as scores and performance will always be tracked. With this data always being monitored, it puts the student at risk of their data being misused or not being anonymized which is not beneficial for the student. Another risk is the over-reliance of AI to make education decisions. This can be harmful to the student as each student learns and develops differently. It is unethical to compare one student’s scores and performance to another. This can cause unwanted beliefs upon specific students that can potentially worsen existing biases and inequalities in education. With more time and research, frameworks that have set guidelines for ethics like Slade, Prinsloo, and Potgieter stated can help decrease ethical issues and set a standard for any future AI model made in the future in education.

Utopian Case

A virtual math tutor would be a powerful tool in a utopian society. In this perfect world, the tutor would be fine tuned to cater to the needs of any student, regardless of their age or ability. It would understand all levels of math from simple arithmetic to number theory and have the ability to explain concepts and problems to the user in a way that works for them. It would be

highly interactive, ideally indistinguishable from a person, and would assist students in overcoming their weaknesses and strengthening their skills.

Aside from the help it provides, the virtual tutor would be easily accessible to everyone, in the form of a website or free application. An online server would allow for the system to constantly be updated, but a downloadable version would allow for wider access. Therefore, ideally something in the middle would be best, where it could be downloaded but receive updates. Lastly, to appeal to a worldwide audience, multiple languages should be supported.

The virtual math tutor would be great for a utopian society, helping promote equality and education. Every user would have an equal opportunity to develop their skills in mathematics and therefore intelligence as a whole. It would be free, bridging the socio-economic gap that exists in education and providing everybody with the same opportunities regardless of their identity. If created correctly, being highly accessible and offering a wide variety of services, a virtual math tutor could help create a utopia.

Dystopian Case

On the other hand, developing teaching into artificial intelligence could have dystopian repercussions. Our app would not be able to single-handedly do this, but if the field grows enough, one could predict a future with some of these scenarios occurring.

As they would likely cost money, AI teaching solutions could perpetuate class inequalities. There are already inequalities with the current system of teaching, where paying more likely will net someone a better education. If teaching gets advanced and personalized enough, these problems can be worsened by creating something like different education “tiers”. There may be something similar to what we have today where those who cannot afford the best education just get what they can, and those who can pay will get the best of the best. Thinking of this in the long-term, those getting better education will likely end up making more money than those with a worse-off education, so these inequalities may begin small but end up great in time.

There also must be steps taken to ensure the AI teaching is done well. One problem that may occur is narrowness in teaching strategies, stunting the learning of those who think differently. Human teachers are generally good at accommodating different learning styles or explaining a topic in a different sense to ease confusion. A poorly written program that tries to do the same may not have this behavior, instead only repeating the same (possibly unhelpful) tips to

the student that is not understanding the material. In time, this may lead to even worsened trends of standardized thinking, where it is thought that there is one right way to do things and no second options. Similarly, the teaching must be interactive to prevent any feelings of isolation or scenarios where students just mindlessly enter in answers.

Using artificial intelligence for teaching has a great power to be good, but it could also do harm if done improperly. To prevent this, programs that assist or replace teaching must be affordable and high-quality. In doing so, many more will be able to access this technology and their time using it will be better spent.

Conclusion

In conclusion, we were successful in creating a working prototype of our AI math tutor MATHstermind. As mentioned before, the growing number of students with access to a computer has unlocked many new learning tools but also created new challenges. The COVID-19 pandemic demonstrated the need for supplemental learning material that is tailored to their learning style and current knowledge.

Our approach was successful at delivering personalized problem sets to users based on their prior accuracy on similar problems. Through an initial quiz the student takes before entering the tool, MATHstermind is able to get a sense of what the student tends to struggle with. It is at this point where MATHstermind allows the user to choose the difficulty of the problems measured by the number of integers in the algebra equation as well as the range of numbers used in the problems. Within each level, our goal is for the student to earn the highest score which in return is the highest reward. This is completed through the student answering each question correctly to master each level. Now, not every student will master a level right away. With more practice, the student will be able to capitalize on the highest score and reward. However, the application currently only offers basic algebra problems and no other subjects that students might need additional practice with like Geometry. Additionally, problems involving computation of fractions are not yet supported.

In spite of these shortcomings, the future of MATHstermind looks bright. Future additions to the AI math tutor include first increasing the dataset of users and providing more informative feedback to students.. The reinforcement learning aspect of the application requires

students to use it and runs on a basic level policy. With more time and knowledge on programming reinforced learning, our application could use better algorithms like Q-learning to find optimal policy, maximize the reward, and assist student's way better. Another future change would be the addition of a better reward system that would give more of a reward if it was a topic the user got it correct but struggled with frequently and less of reward if it was a topic the user got wrong but got frequently correct. Furthermore, this would mean we'd focus more research into intelligent systems using reinforcement learning. Along the way, we learned that a reinforced learning, "agent typically requires millions of training episodes, and such training is generally done in a simulator" (Singla, 4). With more attentive research in future, we believe we can improve on our system such that there is more trained data to better understand the personal needs of each student . Additionally, statistics on students' scores before and after using MATHstermind to supplement their studies to gauge the impact it has on their learning. This will allow us to fine tune the weighting and give the model more information to learn from. Another important planned addition is to add better feedback provided to users based on the type or specific step of each problem they answer incorrectly. Other additions include expanding the branches of math available to practice, different types of questions i.e. multiple choice, comprehension, word questions as well as creating a web based version.

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