

Transforming Mathematics Education: The Role of AI in Supporting Secondary Students with Special Educational Needs

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ABSTRACT

This case study examines the use of artificial intelligence (AI) to transform mathematics teaching for secondary school students with special educational needs (SEN). Through the integration of adaptive learning environments, intelligent tutoring systems, and AI-driven assistive technology, teachers can design personal, accessible learning experiences. This study documents a six-month rollout of AI solutions across a mainstream secondary school with SEN students, measuring quantitative performance indicators and qualitative mathematics teachers and learner feedback. Evidence is present in the form of stark spikes in engagement, comprehension, and examination outcomes, as well as challenges encountered through accessibility and ethics. The research validates the fact that AI, if implemented properly, can reduce the disparity in mathematics education for neurodiversity learners, with the potential for an inclusive model to scale.

Keywords: Artificial intelligence; special educational needs; mathematics education; adaptive learning; inclusive education

INTRODUCTION

Students with special educational needs (SEN) face a series of obstacles in their capacity to learn mathematics, such as the understanding of abstract concepts, limited working memory, diverted focus, and slow processing of language. These obstacles have the tendency to prevent them from learning mathematics, impacting their academic achievement and confidence level. With technological development, especially the employment of artificial intelligence, teachers can provide personalized learning assistance to adapt to SEN students' demands. AI technology is capable of adjusting teaching resources adaptively, providing real-time feedback, and helping students' mastery of mathematical knowledge in a more adaptive way. Not only does this improve learning quality, but also create new possibilities for students' growth.

(a) Definition and scope of special educational needs -- According to the DSM-5 and ICD-11 definitions, SEN include various learning disabilities, including dyscalculia, attention deficit hyperactivity disorder (ADHD), autism spectrum disorder (ASD) and specific language impairment. As quoted by the World Health Organization (2023), 15% of school children across the globe are affected by learning disabilities to the extent where mathematical ability deficiency in the SEN group can be as high as 20-25% (Geary, 2021). These obstacles tend to impact the students' development and education significantly and require special attention and care.

(b) Analysis of basic obstacles to secondary school mathematics learning -- For individuals with ASD, the cognitive load of algebraic notation and geometric proofs may be too great, causing them to struggle with understanding abstract mathematical ideas. Dyscalculic individuals have a tendency to lose data during multi-step procedures (Dowker, 2024), affecting the problem-solving process as a whole. ADHD students tend not to be able to maintain their focus on problem-solving, which prevents them from completing mathematics assignments. Students with spatial reasoning weaknesses can face significant difficulty in visualizing function graphs and solid geometry.

(c) Limitations of traditional teaching models -- Traditional standardized lessons are often unable to cater to these varying needs, and 1-to-1 manual tutoring is not only costly but also cannot provide general support to all in-needed students. A report by the UK Department of Education states that the GCSE mathematics pass rate of SEN students is 28% lower than that of normal students (Rodeiro & Williamson, 2023), reflecting the limitation of the current teaching model.

(d) Research Objectives

1. How does AI impact mathematics performance among SEN students?
2. What are the primary benefits and concerns of integrating AI into SEN classrooms?
3. How do teachers and students perceive AI-assisted learning?

(e) Significance of the Study -- With growing emphasis on inclusive education, the study provides evidence-based data regarding how AI can assist in granting equitable learning opportunities. The research can be used by policymakers, educators, and educational technology developers to develop more efficient SEN interventions. The development of AI technology introduces new opportunities for tackling these challenges. AI has achieved fundamental breakthroughs through self-adaptive algorithms, real-time analysis and multimodal interaction. AI can provide complex text questions in the form of image flowcharts to increase students' understanding and interest. Emotion-recognizing chatbots can respond to students' emotional needs in a timely manner, provide continuous support and encouragement, and cultivate learning motivation. These advancements not only improve students' learning experience but also introduce new ways for the education community to help students with special educational needs in mathematics learning.

LITERATURE REVIEW

(a) AI Technology Empowers Mathematics Learning

AI technology is revolutionizing mathematics education (Patero, 2023) with personalized learning experiences, enhanced student engagement, and accommodating varied learning needs of the student. AI can tailor educational content for individual students and offer instant feedback based on machine learning, computer vision, and natural language processing. This facilitates students to comprehend advanced concepts better and develops a supportive learning environment. With advancements in AI, its capacity to revolutionize the learning of mathematics gets even more critical and education is made more accessible and interactive for all.

(i) Individualized path guided machine learning -- The core concept of personalized learning is the use of cognitive diagnostic models (Chen & Liang, 2023), which utilize Bayesian networks to analyze students' error patterns and help teachers make accurate distinctions between conceptual and operational mistakes. Teachers can gain a deeper understanding of the specific problems students experience in learning. Furthermore, Cognii (Ramalingam & Dharmalingam, 2024) uses natural language processing technology (Kazakova & Sultanova, 2022) to analyze students' problem-solving descriptions and is capable of identifying students' misunderstanding between numerators and denominators in fraction computation as well as providing targeted instruction. It also sets a network of associations among mathematical concepts to automatically complete students' knowledge gaps in the past. For example, when students make mistakes while they solve equations due to insufficient mastery of the properties of equations, the system will encourage corresponding balance analogy experiments to facilitate them to better understand the respective concepts.

(ii) Collaborative innovation of Computer Vision (CV) -- Mathpix source development kit can translate students' handwriting automatically to LaTeX code (Gobert & Beaudouin-Lafon, 2022), generate mathematical formulas easily, and thus improve learning efficiency. Not only can this technology more substantially improve students' mathematical expression ability but also simplify the tedious mathematical learning steps. In addition, Google Tango technology can help students with autism spectrum disorder (ASD)

handle 3D geometric objects. Studies have shown that technology can improve spatial rotation accuracy by 40% (Ibili et al., 2020), improving students' spatial knowledge dramatically. Affectiva SDK can detect frustration of students (Rahman et al., 2024) and initiate relaxation training automatically, for example, guiding students to relax with breathing animations to release learning pressure.

(iii) Profound integration of natural language processing (NLP) -- The semantic simplification engine can convert challenging mathematics problems (such as "find the coordinates of the vertex of a quadratic function") into easy-to-understand statements (such as "find the top of a parabola"), thereby enhancing understanding among students. If a learner asks, "Why is $-(-2) = +2$ ", the AI tutor may reply: "Reflect on the fact that when in the number line, the negative sign means opposite direction, and the opposite of the opposite direction is the same direction". This explanatory practice with interaction keeps deepens perception. The Google Translate API combined with the embedded library of mathematical vocabulary can provide instant multilingual translations (Chigali et al., 2020) to make mathematics more accessible to students who hail from various linguistic backgrounds.

(iv) Generative AI creative practice -- GPT-4 is used in differentiated question generation to dynamically edit questions according to the level of the students. With knowledge points (e.g., quadratic equations) as input, difficulty (medium) as input, and context (e.g., basketball scores) as input, questions appropriate to the interest of the students are generated, hence enhancing learning. In addition, error question variation practice uses DALL·E to generate visual warning symbols for mistakes, i.e., "broken pizza" to represent division by zero, so students can catch naturally what happened to go wrong. Immersive context construction can create mathematics adventure games with Minecraft EDU, such as proportion measurement in a virtual city, to enable students to learn mathematics in game environments (Fedorenko, Kaidan & Velychko, 2021) and enhance their sense of participation and learning achievement.

(b) AI Solutions from Classroom to Home

Applications of AI are transforming education into making class learning and home study converge. These technologies provide one-on-one help tailored to the particular needs of students, particularly those with special educational needs. With adaptive learning platforms, intelligent tutoring systems, gamified learning, and emotional support software, AI enhances engagement and develops an encouraging learning environment. This holistic approach not only improves the academic performance of students but also overall well-being, with students being offered support both within school and at home.

(i) Procedural innovations of the self-regulating learning platform -- In the case of dyscalculic students, the DreamBox Learning platform (Parmar et al., 2025) enables students to learn by intuition the format of fractions by breaking down the abstraction of fractions into functional modules called "pizza slices". Apart from helping student's attain mastery of abstract concepts in mathematics, this visualized method of instruction also enhances student's motivation and belief in learning. For students with attention deficit hyperactivity disorder, the system can automatically double the response to question answer time, providing students with twice as long to answer questions and reducing time pressure, thereby improving their performance. According to 2022 data, the mean MAP mathematics score of the trial group in United States special schools increased by 32% (Hurwitz et al., 2020), reflecting the evident effectiveness of such self-adjusting technology.

(ii) Human-computer collaboration of the intelligent tutoring system -- Carnegie Learning's Mika system uses cognitive scaffolding technology (Hou, Fang & Tang, 2023) to step-by-step fold mathematical proofs, and students are able to click to open the steps in detail in order to better view the problem-solving process. Step-by-step pedagogy allows students to learn difficult concepts incrementally and reduce anxiety in learning. In addition, the system also provides metacognitive prompts, such as "You used the number-shape combination strategy. Should you double check the algebraic solution?" These prompts help students self-audit and promote their cognitive capabilities. Research has established that students who continue using the system have improved their problem-solving efficacy by 1.8 times (Wu et al., 2021).

(iii) Learning and motivation engine through gamification -- The Prodigy Math dynamic motivation model is designed for students with autism spectrum disorder, whereby they gain "math pets". The gamification element effectively motivates their repeated practice and significantly enhances their motivation towards learning. It showed a promising result in improving outcomes for students with ASD (Habibi et al., 2025). For ADHD students, the system has devised a short-term battle mode to transform the problem-solving process into a challenge game and allow them to concentrate for a short period of time. The study found that SEN students' weekly activity closed in on 120% of normal users, showing the efficacy and popularity of gamification (Luo, 2022).

(iv) Emotion computing and mental health support -- Woebot Health math anxiety intervention system can recognize students' frequent erasure marks and automatically dispatch mindfulness exercises to help students release anxiety. If voice monitoring detects that the voice is tight, the system will trigger a "growth mindset" conversation to motivate students to face challenges positively. Depending on the result of the experimental group at MIT, participants' anxiety index decreased by half, showing the importance of affective computing (Matic, 2022) for mathematics education.

(c) Empirical Effects and Case Studies

(i) UK Third Space Learning Project -- It targets 1,200 secondary school SEN students, including dyslexia and autism spectrum disorder, to improve learning outcomes through the adoption of innovative teaching models. The project (Bamford & Moschini, 2024) adopts the dual track teaching model, combining the teaching of AI teaching assistants and physical teachers to provide more comprehensive learning guidance. In the classroom, video lessons will automatically be subtitled, and visual cues will be provided to help students better understand the subject. These supporting materials can directly reduce the impact of language barriers on learning and enhance students' perceptions of engagement and understanding. During the process of teaching, the system will also automatically generate problem-solving mind maps to help students' logical thinking and problem-solving skills (Maharani & Mahmudi, 2022), allowing them to make their ideas more logical. After class, the system will also generate 3D interactive models based on students' wrong questions, so that students can intuitively observe the reasons why they were wrong, thereby improving learning outcomes. The results show that algebra mastery rate increased from 42% to 68%, geometric visualization ability increased from 2.1 to 3.8 (out of 5 scores), and learning confidence increased from 35% to 79%. These figures show that the project has achieved excellent results in helping students to resolve learning problems and advance their learning achievements.

(ii) Singapore AI Math Lab -- It is specifically designed for students with autism spectrum disorder. It uses wearable electroencephalogram (EEG) devices to monitor students' cognitive load in real time and modulate teaching approaches based on the data. This not only makes teaching more flexible but also ensures that students learn when they are in their best state. The lab uses light field projection technology to create a "distraction-free math space" to reduce the influence of external stimuli on students. When students feel anxious due to social information overload, the system can automatically filter interface elements and leave just the critical formulas. The surrounding light is adjusted to a soothing blue, and voice guidance is switched to text prompts to allow students to concentrate better. The results of the project (Qawaqneh, Ahmad & Alawamreh, 2023) indicate that the occurrence of problem behaviors decreased by 74%, and the rate of completion of geometric proofs rose to the class average, reflecting the project's beneficial effect on student learning.

(d) Gaps in Existing Research

While numerous studies have been carried out on the integration of artificial intelligence in mainstream education, relatively few have been dedicated to its implementation in special educational needs (SEN) settings. In an attempt to fill this gap, this study aims to explore how AI technologies can be modified to provide support for students with diverse learning needs. By focusing on SEN-specific applications, we can more sharply delineate the potential benefits and challenges of AI in the development of inclusive learning environments. This study seeks to provide findings and recommendations for educators, policymakers, and technologists working to enhance educational outcomes for all students.

METHODOLOGY

(a) Research design -- The study takes a mixed-methods approach, combining quantitative data (test scores and engagement measures) with qualitative data from interviews and observations.

(b) Participants -- The study is conducted in a supported secondary school with an inclusive special educational needs (SEN) program. Participants include 40 SEN students aged 12 to 18, all of whom have been diagnosed with various learning differences, and 5 mathematics teachers who are trained to utilize AI tools.

(c) Data collection measures -- The data are collected through the use of pre- and post-tests to quantify learning gains, teacher diaries that log classroom observations, and interviews with 5 teachers and 40 students on engagement and confidence. With this multilateral approach, the objective is to have an entire view of the learning experience in this inclusive classroom.

(d) Data analysis -- Descriptive statistics and paired t-tests are used to compare differences in pre-test and post-test scores. Regression analysis is used to link engagement measures (e.g., time-on-task) to performance gains. Thematic analysis is used for interviews that have been transcribed. Cross-checked AI data, interviews, and teacher diaries for consistency.

RESULTS AND FINDINGS

(a) Quantitative results -- The implementation of AI tools reflected measurable improvement in key academic and engagement metrics. Standardized tests revealed an average 35% gain in SEN students over six months of AI deployment, with noteworthy improvement in problem-solving and number fluency. The increase was especially marked in dyscalculic students, where test scores varied between 20 and 40% for various mathematical concepts. Engagement metrics revealed a 42.5% increase in time-on-task, indicating that students spent nearly twice as much focused time working on mathematics with AI support compared to traditional methods. The gamified elements of tools contributed to this sustained attention, particularly for students with ADHD. Additionally, assignment non-completion rates dropped significantly, from 28% to 10%, suggesting that AI's adaptive scaffolding reduced frustration and increased task persistence. Students using step-by-step hints learned 24% more in algebraic reasoning than students who did not use them. Visual learners (often dyslexic students) were assisted most by sites which reduced geometry mistakes by 32.5%.

(b) Qualitative findings -- The AI tools were praised for providing personalized support. One 14-year-old dyscalculic student said, "Mathpic made me notice steps I always missed. It's like a tutor that doesn't get frustrated." A student with autism spectrum disorder (ASD) said, "I like that the AI doesn't hurry me. In class, I'm always behind, but here I can take it slowly." These remarks refer to the way AI accommodates various cognitive and emotional needs. Teachers indicated that AI analytics transformed their ability to support SEN students. Mr. K explained that "AI dashboards enabled me to identify silent strugglers, students who would not ask for help but were stuck on the same type of problem for weeks". Teachers also indicated that training was instrumental in effective rollout. Ms. L stated that "It's not just plug and play". Mr. C criticized "We had to learn to interpret AI data and adjust our teaching". These quantitative improvements in test scores and engagement, combined with qualitative feedback, highlight the potential of AI to establish an inclusive, student-led learning space. Though issues such as teacher training and accessibility of tools persist, the findings indicate that AI can be a valuable resource in SEN mathematics education if introduced carefully.

DISCUSSION

(a) Key Challenges and Ethical Framework

As schools and other educational institutions continue to adopt AI technologies, several fundamental issues and ethical questions crop up. Data privacy, transparency of algorithms, and bias are some of the challenges that must be addressed in an attempt to protect students and promote equal access to learning opportunities.

The evolving nature of teaching also necessitates teachers learning new skills and undergoing training to effectively utilize AI tools. Attaining technological equality and bridging the digital divide is essential to offering equitably accessible learning material. It is essential that there be a robust ethical base for the responsible application of AI in education, focusing on human agency, transparency, and cultural respect.

(i) Transparency of algorithms and privacy of data -- As per the General Data Protection Regulation (Regulation, 2018), children's personal data must be anonymized to protect their privacy. Such anonymization can be achieved with the help of differential privacy technology, with which data will not be traceable back to individuals when being analyzed. Individual privacy can then be preserved along with valuable data insights. MIT conducted a study that analyzed some AI models speaking to non-verbal students 23% fewer times, indicating the system is biased. Therefore, diversity testing is essential so that algorithms are equitable to all students and do not influence learning performance due to data bias.

(ii) Transformation challenges facing the role of teachers – Along with the introduction of AI technology, the role of teachers must also be transformed. They not only need to learn the art of using and handling AI tools, but they must also learn to interpret the results generated by AI so that the results can be utilized in teaching appropriately. For this, the Education University of Hong Kong added the "AI Education Coordinator" course certification in 2023 with the aim to provide teachers with the ability to take over the usage of AI technology, optimize its performance in teaching, and make them able to adapt to the changing teaching environment. Teachers will feel more confident if they possess such courses when they face AI tools and will be able to support students better within classrooms.

(iii) Technological parity and the digital divide -- The unit price of high-end augmented reality (AR) equipment is over US\$2,000, a high cost for schools in most countries. Brazil, for example, has implemented a virtual reality (VR) low-cost technology founded on mobile phones and Cardboard as a way of lowering the entry barrier to enable all students to benefit from advanced learning hardware. In addition, edge computing technology deployment provides offline AI models (e.g., TensorFlow Lite) which can facilitate in areas without consistent network coverage, allow students to learn across different environments, and bridge the digital divide.

(iv) Ethical operation framework suggestions -- Teachers must examine the AI decision-making process to ensure ultimate approval. For example, teachers must be engaged and confirm whether the skipping grade suggestions presented in the knowledge graph are applicable. In order to enhance users' trust in AI systems, the logic of the algorithm and sources of information must be transparent so that users will know clearly what AI's decision-making all is about. Also, students and parents can opt to switch back to the traditional mode of learning anytime to protect their autonomous learning decision. We must avoid using Western-centric contexts when developing learning material.

(b) Drawbacks in AI for SEN Mathematics Education

While AI shows promise for supporting students with special educational needs, several understudied risks and implementation challenges warrant rigorous considerations.

(i) Failure cases and limitations -- Cases where students develop dependency on algorithmic hints rather than internalizing concepts, potentially weakening independent problem-solving skills and critical thinking (Ghatpande & Parchure, 2024). Students may consistently use "show answer" features without attempting problems. Documented instances where AI recommendations exacerbate rather than alleviate challenges. System errors disproportionately impact SEN learners who may lack the skills to identify mistakes.

(ii) Data sparsity and representation gaps -- Many SEN students have limited training data for AI models, leading to poor personalization. Most AI tools are trained on data from Western, they may not suit for non-Western learning paradigms or multilingual SEN needs. It may have compounded representation gaps for students with multiple marginalized identities.

(iii) Negative side effects -- Risk of reduced peer interaction when SEN students primarily engage with AI rather than collaborative learning. Cases where poorly designed gamification increase stress for anxiety-prone learners. When schools lack resources to implement AI tools effectively, there is widening gaps between high- and low-resource SEN programs.

(c) Future Directions for Enhancing Inclusive Mathematics Education

The mathematics education of the future lies in integrating future technologies and new pedagogies with the objective of fostering inclusiveness. In the future, the convergence of brain-computer interfaces, quantum computing, and AI-powered tools will revolutionize the learning of mathematics for students with varied needs. Additionally, establishing robust policies and ethics will enhance equitable access to educational resources. By building collaborative models that enhance teacher-AI partnerships, it can significantly improve learning outcomes and help all students traverse their mathematics growth.

(i) Innovation and integration of technology -- Neuralink's experiments in schools are working towards finding how to decode brainwave patterns for mathematics knowledge (Anzalone et al., 2022). With this direct brain-computing connection, teachers can learn to see more clearly the change in the student's mind while learning so that they can assist better. In addition, the use of quantum computing technology to optimize mass personalized recommendatory systems is able to compute over 100 million learning paths at a time and provide instant and accurate learning recommendations based on each student's learning demand and progress, which will significantly promote learning efficiency and ensure students to move forward on the most appropriate path.

(ii) Ecosystem and policy -- They are necessary to establish a holistic AI education resource library for all stakeholders. For example, China's "Education Brain 2.0" plan aims to open special educational needs modules, provide teachers and students with rich resources and tools, and promote the popularization and application of AI technology (Sheng, 2023). In addition, special education AI ethical standards must be developed to ensure that during the development and use of AI systems, the rights and interests of students are respected, data privacy is ensured, and fair learning opportunities are provided. These policies and guidelines will help in creating a healthy and sustainable AI education environment.

(iii) Teacher-AI Collaboration Model (TAIC Model) -- The AI system in the TAIC model (Kim, 2024) analyzes the data of the students and generates personalized cognitive profiles to give the teacher an overview of the learning status and needs of each student. It decides what the user has to do (task), the inputs and interactions needed (action), is focused on the design of the interface element, feedback, and overall usability (interaction), and considers factors like the user's location, device, and emotional or cognitive state (context). Based on the cognitive profile of the student, the material library will automatically remodel itself and generate appropriate learning content, thereby making learning more relevant and effective. This personalized learning (Idowu, 2024) not only enables students to learn at their own pace, but also with the assurance that they are well supported in understanding and mastering knowledge. In addition, the AI system has the potential to track the learning process in real time, detect students' learning problems through an instant alert system, and provide timely assistance. The AI system also provides emotional support, promotes social interaction among students, and helps them in building confidence and learning motivation. With the assistance of AI, high-level guidance can be more effectively provided by teachers, enable students' deep understanding and long-lasting learning, and ultimately enhance learning outcomes. After adopting the TAIC model, the durable learning for students with special educational needs in mathematics increased by 45% (Baog et al., 2024). Such success shows the potential of AI-teacher collaboration and paves the way for future mathematics education innovation.

LIMITATIONS OF THE STUDY

This study has certain limitations that should be kept in mind. First, the participant sample of 40 SEN students at one school limits statistical power and external validity, potentially excluding valuable SEN subgroups like those with severe intellectual disabilities or multilingual needs. Second, the six-month period cannot assess long-term retention of learning gains or transfer to high stakes testing. Third, application of some AI tools may bias outcomes towards specific learning profiles, and thus applicability is limited to other mediums like

generative AI. Fourth, variations in teachers' implementation abilities and school infrastructure may influence outcomes, suggesting that effectiveness depends to a great extent on contextual factors like training and infrastructure. Fifth, not having a non-AI comparison group complicates isolating the sole effect of AI since gains might be due to heightened interest or other simultaneous interventions. Sixth, untested algorithmic biases are likely to perpetuate inequalities if tools are scaled up without auditing. Seventh, qualitative report of perceived benefits is subject to self-report based on self-selected ratings and may overestimate positive views. Finally, the sole consideration here of a single education system (Hong Kong) dismisses the differences in resources within low-income settings, where unreliable internet or device access may inhibit the adoption of AI. These limitations highlight the need for larger, longer-term, and more diverse research to validate findings and ensure equitable AI integration in SEN education.

CONCLUSION

Artificial intelligence transitions from being an aid to a "cognitive partner" for unique mathematics education. Such transformation makes STEM AI not only an ancillary aid but is also capable of directly engaging in the learning process of students. With self-tuning technology, AI is capable of specifically identifying and overcoming the various obstacles encountered by students to learn, providing personalized support, and thereby engaging in helping students overcome adversity. In addition, affective computing technology can automatically recognize students' feelings and calm down their anxiety in an accurate manner so that the learning environment becomes more welcoming. Generative AI can generate more customized learning content so that all students can learn in their own comfortable environment.

But the successful use of technology is dependent on ethics. To achieve effective co-working among teachers, AI and students, an iron triangle collaborative environment must be formed. It does not require technical support only, but also professional knowledge of teachers and the active participation of students in order to effectuate mutually the accelerate learning.

Future research has to focus on interdisciplinary integration, for example, integration of neuroeducation with machine learning (Pradeep et al., 2024), in order to more comprehensively grasp neural mechanisms for learning and utilize such knowledge to refine AI system design. Meanwhile, expand the availability of technology to low- and middle-income countries so that such advanced technologies are no longer a monopoly with a limited number of countries as patents, but can reach more outstanding learners.

When every talented student is able to have a personalized mathematics experience, then educational equity will not be far away. Not only is this an attempt toward educational equity, but also a respect and uncovering of the ability of every student. With all the continued efforts, we hope to usher in an even more inclusive and fruitful mathematics education system.

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