

Conceptual Understanding of Mathematics in Artificial Intelligence Era: A Comparative Study of Pre and Post-CHATGPT Access among Student Teachers

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Abstract: The rapid integration of artificial intelligence (AI) in education, particularly tools such as ChatGPT, has introduced both opportunities and challenges for enhancing learning outcomes. This study examined the impact of ChatGPT on mathematics understanding. It compared teacher education students with and without access to the tool. The study was conducted at Mansa College of Education and used a concurrent mixed-methods approach. The study focused on quantitative analysis of assignment and test results from the 2018 and 2024 cohorts. While the qualitative aspect was used to get perspectives from students through focus group discussion and phone interview. The findings indicated that while 2024 students (with ChatGPT access) performed better on assignments, the 2018 cohort (without ChatGPT) outperformed them on tests which suggested that ChatGPT aids task completion but does not fully support deeper conceptual understanding. Qualitative results revealed that ChatGPT made concepts clearer and facilitated faster completion of assignments but it also posed challenges in obtaining feedback and reinforcing unclear concepts. The study concludes that ChatGPT enhances task efficiency, however, it limit understanding of the concepts. This emphasize the need for assessments that promote active engagement and critical thinking. The study recommends using quizzes and projects in place of written assignments in order to foster a deeper grasp of mathematics.

Keywords: Conceptual Understanding, Artificial Intelligent (AI), CHATGPT, Mathematics Education.

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I. INTRODUCTION

The 21st century heralded a new era of technological advancement that has permeated every aspect of society, shaping the ways in which people live, work, and learn. Technological innovations have become critical drivers of societal transformation, from the advent of the internet and smartphones to the proliferation of big data and artificial intelligence (AI). The integration of these technologies into education systems represents a major shift in how knowledge is shared and acquired and redefines traditional teaching methods to meet the demands of the Fourth Industrial

Revolution (4IR). The 4IR, characterized by the fusion of physical, digital, and biological systems, has reshaped industries and labor markets, emphasizing the need for advanced technological skills and adaptability. Education systems worldwide have evolved in response, adopting Education 4.0 frameworks to prepare learners for a technology-driven future (Messais et al., 2018). This transformation was notably accelerated by the COVID-19 pandemic, which disrupted conventional education systems globally, prompting a rapid shift to online learning platforms and digital tools. Post-pandemic, these tools remain integral and foster greater collaboration between human intelligence

and technology (Duong, Can & Nguyen, 2024). In this era, the Internet of Things (IOT), cyber-physical systems, and big data analytics have become ubiquitous, enabling unprecedented connectivity and data-driven decision-making (Messais et al., 2018). Among these advances, artificial intelligence has emerged as a transformative force in education. AI-powered applications, such as virtual assistants and adaptive learning platforms, have enhanced the personalization and efficiency of educational experiences. Tools such as ChatGPT, an AI-based conversational model developed by OpenAI (Connolly & Watson, 2023), have gained prominence in higher education, including teacher training colleges. The capacity of ChatGPT to provide instant feedback, clarify complex concepts, and generate explanations tailored to individual queries positions it as a revolutionary tool in fostering conceptual understanding (Bai, Liu & Su, 2023).

Despite the benefits and opportunities offered by ChatGPT and its impact on learning of mathematics, there remains a very low number of peer reviewed articles covering the subject with regard to higher education (Rudolph, 2023). Furthermore, the need to uncover the differences between students pre and post access to ChatGPT has become of great concern to scholars. This is because uncovering such knowledge has potential to aid in further development of these AI platforms, increase access to them and possible re-invent the whole process of learning mathematics in the current AI enabled environment. While several studies have highlighted the transformative potential of ChatGPT in education, there remains a gap in understanding its specific effects on mathematical problem-solving and conceptual understanding in the context of teacher education. Mathematics, with its reliance on abstract reasoning and logical problem-solving, presents unique challenges and opportunities for AI integration. It is against this background, this study sought to: evaluate the role of AI in mathematics education at Mansa College of Education; explore how the integration of ChatGPT impacts students' conceptual understanding and performance in mathematics. The study focused on both the opportunities presented by this technology and the limitations experienced by teacher education students.

II. LITERATURE REVIEW

The technological advances of AI present opportunities and benefits that can be utilized by society today. The importance of AI transcends a number of disciplines, therefore its application in the education sector cannot be over emphasised. AI has been described as a process that uses computer systems and/or other machines to mimic human intelligence (Mohamed et al., 2022). There are a number of AI platforms available today but ChatGPT is one of the most popular and advanced Chatbot (Gouia-Zarrad & Gunn 2024). With regard to mathematics education, Ellis and Slade (2023) indicate that ChatGPT is capable of generating mathematical

theorems, solve problems as well as aid the learning of mathematical concepts.

A study conducted by Pardos and Bhandari (2024) compared the learning gains of ChatGPT to human tutor-authored help across four mathematics problem subject areas and found that only the ChatGPT condition produced statistically significant learning gains compared to a no-help control. The study showed that the performance of students that used ChatGPT in their studies in mathematics were able to score better performance levels than those that used traditional methods of non-AI enabled learning. This helped the current authors hypothesize the value and gains that ChatGPT can offer in the teaching and learning of mathematics at all levels including teacher education. A similar study conducted in Finland by Adelegan (2023:2) which focused on performance of students in Mathematics, Science and English showed that the use of ChatGPT in teaching and learning improves the level of knowledge acquired by participants. The study showed that there are significant differences between learners that learned without access to ChatGPT and those that learn with the aid of the Chatbot. The justification therefore of whether or not ChatGPT is of benefit lies in its ability to help students work smartly through tasks and improve their efficiency in understanding mathematical concepts. It is important to note that ChatGPT reduces the time spent looking for solutions to problems (Duong et al, 2024).

A comparative look at performance with or without ChatGPT conducted by Kumar, Singh, and Sharma (2022) showed that there were significant limitations of ChatGPT enhancing student performance. The study argued that due to limitations of the chatbot to fully understand certain contextual complexities in mathematics, it presented potential for misinformation. The fact that ChatGPT struggled with complex mathematical concepts affected the way that students understood these concept and when compared to human-tutored students, this was not the case as human tutors were well able to handle these complexities involved in mathematics education. Conversely, Connolly and Watson (2023) indicated that students that used ChatGPT had more personalized learning experiences which enabled them to adapt more easily and acquire problem solving skills than those who were human-tutored.

This implies that with ChatGPT learning can be adapted to the varying educational needs of students. Over and above, the study posits that because ChatGPT provides immediate feedback to the learners, it enables real-time access to solutions thus enhancing problem solving skills in students. Further, ChatGPT provides a much richer experience to mathematics teacher trainees in that they are able to interact with an artificial tutor that can attend to their learning needs well beyond the confines of time frames available in the learning institutions. Provided there is internet access, students

can chat with the ChatGPT and gain insight on problematic areas in their study. However, it was noted that there was more dependency on ChatGPT than own-personal task handling in students exposed to the use of this form of technology which was not the case in the students that depended on human-tutoring (Mai, Da & Hanh, 2024).

There are concerns from education community owing to possibility of students accessing information without citing appropriate sources. The other aspect has to do with the limitations of ChatGPT to fully comprehend contextual difficulties embedded in mathematical problems. As a result it may give inaccurate and irrelevant responses to a user (Kumar et al, 2022; Ellis & Slade, 2023). Its failure to handle complex mathematical concepts and consequent errors and inconsistencies in its responses is likely to promote misconceptions with regard to understanding of mathematical concepts in general (Da, Hanh & Mai, 2023). This is because ChatGPT relies on pre-existing data which can therefore; provide students with incomplete or out-dated information (Watson, 2023). Similarly, the use of ChatGPT has the potential to provide a defective coaching system on which over dependency may be detrimental. There are also concerns of unethical use of ChatGPT by student teachers and lecturers. The concern hinges on the fact that the training of teachers that can only “parrot” what is generated by ChatGPT is likely. There is the need therefore, for educators to emphasize the ethical use of ChatGPT as they interact with students in their daily learning activities of mathematics (Adelegan, 2023; Ellis & Slade, 2023).

Despite the increasing research on the impact, benefits, and challenges of integrating ChatGPT in mathematics education, a significant knowledge gap persists. Specifically, there is a scarcity of studies investigating the conceptual understanding of mathematics particularly at the teacher education level (Gouia-Zarrad & Gunn, 2024). This gap is even more pronounced in the context of Zambia.

III. THEORETICAL FRAMEWORK

The study was guided by the Cognitive Load Theory (CLT) proposed by Sweller (1988). It is an instructional theory based on the structure of human cognition. The theory posits that the working memory has a limited capacity and it is only able to hold a small amount of information at a time. It is also responsible for directing attention as well as coordinating cognitive processes (Sweller, 2011). On the other hand long term memory is said to have an endless capacity. There are two main types of load that may affect the learners comprehension of concepts and these are; Intrinsic and Gemane. Intrinsic load has to do with the complexity of the materials while germane load has to do with processing information so as to build schemas in the long term memory and learn new information. Thus, in order to avoid overloading the short term memory and maximise learning,

there must be application of techniques by the educator that act as scaffolds for enhancement of learning and support to learners in their immediate environment. This study therefore, saw ChatGPT as a scaffolding tool that provides learners with enhanced potential for conceptual understanding of mathematics education thereby supporting the germane load (Bai, et al, 2023). Secondly, mathematics is characterized by complex problems that requires mental effort to solve. As such ChatGPT reduces the mental effort needed by students to solve these problems. This is achieved through helping learners to get detailed feedback to mathematics questions with ease as well as reduce memorization of concepts.

IV. METHODS

This study adopted a concurrent mixed-methods approach. It allowed for simultaneous collection and analysis of both numerical and narrative data to explore the impact of ChatGPT on conceptual understanding in mathematics education among teacher education students. The study was conducted at Mansa College of Education and focused on first-year students pursuing a Diploma in Primary Education. Two cohorts of students were targeted: the 2018 cohort, representing pre-ChatGPT access, and the 2024 cohort, representing post-ChatGPT access. These cohorts were purposively selected to enable a comparative analysis of performance and experiences. The study employed a purposive sampling technique to select the two cohorts, as they were most relevant to the research objectives. For the qualitative component, a focus group interview was conducted with five students randomly selected from the 2024 cohort. Additionally, one student from the 2018 cohort was conveniently selected and interviewed via phone. Assignment and test results for each cohort were obtained from the Department of Mathematics Education and the College Examinations Section. These results provided quantitative data on students’ performance in mathematics before and after the introduction of ChatGPT. Semi-structured interviews were conducted with selected students. The interviews were audio-recorded with participants’ consent and later transcribed for analysis.

Permission was obtained from the relevant authorities at Mansa College of Education. Participants provided informed consent before participating in the study. Anonymity and confidentiality were upheld throughout the research process, and data was securely stored to prevent unauthorized access.

V. DATA ANALYSIS

The data analysis involved both quantitative and qualitative methods. Quantitative analysis began with a normality test conducted on assignment and test scores to determine the appropriate statistical tests for the data. Following this, an independent samples t-test was performed using SPSS version 27.0 to compare the performance trends of the two cohorts and identify significant differences in their conceptual understanding of mathematics. Homogeneity test was performed to fulfil the requirement for performing the t-test. Descriptive tests were also utilized. Qualitative data from interviews were audio-recorded, transcribed, and manually coded for analysis. Through an exploration of the transcript,

themes were identified to describe the opportunities and challenges of using ChatGPT. This thematic analysis provided an account of students' experiences and perspectives, which complemented the quantitative findings.

VI. RESULTS

A. Quantitative Results

To determine the appropriate statistical test for analyzing the assignment and test scores of the 2018 and 2024 cohorts, the Shapiro-Wilk test of normality was conducted. This test assessed whether the data follows a normal distribution, which is a prerequisite for parametric tests such as the independent samples t-test. The results are presented in Table 1.

Table 1. Normality Test Results

Scores	Statistic	Df	Sig	Normally Distributed
Assignment	.959	32	.258	Yes
Test	.979	32	.780	Yes

The p-values (Sig.) in table 1 for all the scores were greater than the alpha value of 0.05. This indicates that the null hypothesis of normality could not be rejected. Specifically, the assignment and test scores for both 2018 and 2024 cohorts were approximately normally distributed, as evidenced by p-values. Given that the data met the assumption of normality, an independent samples t-test was deemed appropriate for comparing the assignment and test scores between the two cohorts.

Levene's test for equality of variances was conducted to assess whether the variances of the assignment and test scores were equal between the cohorts. Equal variances are an important assumption for conducting an independent samples t-test. The results of Levene's test are summarized in table 2.

Table 2. Homogeneity test of variance

	F	Df	Sig
Assignment	.786	66	.379
Test	1.604	68	.210

The p-values for Levene's test (in table 2) for both the assignment scores (0.379) and test scores (0.210) are greater than the alpha level of 0.05. This indicates that the null hypothesis of equal variances cannot be rejected. Therefore, we concluded that the variances of both the assignment and test scores were equal across the 2018 and 2024 cohorts.

Since the assumption of equal variances was met for both the assignment and test scores, the results of the independent samples t-test with the assumption of equal variances were considered valid. The independent samples t-test was performed to compare the assignment and test scores between the cohorts. The results are presented in Table 3 below:

Table 3. Independent Sample t-test Results

	t	Df	Sig (2-tailed)
Assignment	-4.568	66	.557
Test	5.116	68	.000

The p-value for the assignment scores is 0.557, which is greater than the significance level of $\alpha = 0.05$. This indicated that there was no statistically significant difference between the 2018 and 2024 cohorts in terms of assignment performance. Therefore, any observed difference in assignment scores between the two cohorts could be attributed to random variation rather than a true effect. In contrast, the p-value for the test scores was 0.000, which is well below the threshold of $\alpha = 0.05$. This suggests a statistically significant difference in the test performance between the two cohorts. Descriptive statistics were also used to further analyze the assignment scores of the two cohorts, the results are depicted in Table 4 below.

Table 4. Descriptive Statistics Results (N=68)

	Cohort	N	Mean	Standard Deviation	Minimum	Maximum
Assignment	2018	32	82	6.88	68	98
	2024	36	90	7.74	70	100

Table 4 reveals that the 2024 cohort had slightly a higher average assignment score ($M = 90.00$) compared to the 2018 cohort ($M = 82.00$). The descriptive statistics show that the 2024 cohort had both a higher mean score. The standard deviation for the 2024 cohort (7.74) was slightly higher than that of the 2018 cohort (6.88), indicating a greater variability in scores within the 2024 group. These findings suggest that the 2024 cohort's scores were generally higher on average, with more students achieving closer to the maximum score. To better understand the test performance of the two cohorts, descriptive statistics were computed and are presented in Table 5 below.

Table 5. Descriptive Statistics Results (N=68)

	Cohort	N	Mean	Standard Deviation	Minimum	Maximum
Test	2018	32	62	13.17	16	94
	2024	36	43	16.00	6	82

Table 5 reveals a notable difference in performance between the two cohorts. The 2018 cohort achieved a higher average test score (mean = 62) compared to the 2024 cohort (mean = 43). This indicates that, on average, the 2018 students performed better on the test. Additionally, the standard deviation for the 2024 cohort (16.00) is higher than that of the 2018 cohort (13.17), suggesting greater variability in scores within the 2024 group. In contrast, the scores for 2024 cohort spanned a wider range, from a minimum of 6 to a maximum of 82. Notably, the 2018 cohort achieved a higher maximum score and had fewer instances of extremely low scores. These results suggest that the 2018 cohort demonstrated stronger overall performance in the test compared to the 2024 cohort.

B. Qualitative Results

➤ Focus Group Interview and Phone Interview

• Opportunities and Benefits of ChatGPT

Findings from both the focus group discussion with five student teachers from the 2024 cohort and a phone interview with a student teacher from the 2018 cohort revealed the opportunities and benefits of ChatGPT in academic activities, particularly its role in enhancing efficiency, problem-solving, and learning experiences. Participants in the focus group revealed several opportunities presented by ChatGPT, including its ability to verify solutions and provide alternative problem-solving methods. For example, ST2 noted, *"I use ChatGPT when I am trying to solve Mathematics just to check if the answers I have come up with are correct,"* while ST1 added, *"ChatGPT actually elaborates maybe two or more methods that I can use to come up with solutions."* Furthermore, the tool was also recognized for its utility in formal writing and mathematical tasks. ST2 shared, *"I command it to write the assignment in paragraphs with citations, and it also provides a list of references,"* while ST5 observed that ChatGPT has the ability to summarize texts and simplify difficult mathematical concepts which saves

significant time, noting, *"Within a minute, it can elaborate a lot of things and solve questions."* Similarly, the phone interview with the 2018 student teacher emphasized the efficiency of AI tools compared to traditional resources like Google and library books. The student noted, *"With ChatGPT, it gives you exactly what you need,"* contrasting it with the time-intensive process of traditional research methods.

• Limitations and Challenges of ChatGPT

While the benefits of ChatGPT were widely acknowledged, participants also identified several limitations and challenges that hinder its effectiveness, especially in fostering conceptual understanding in mathematics. One recurring issue was the platform's inconsistency in providing accurate or reliable answers. ST3 explained, *"When you command it again for the same question, it brings different answers,"* while ST4 shared, *"ChatGPT gave me two incorrect solutions to the same problem."* In addition, participants revealed operational challenges, such as interaction limits, word count restrictions, and difficulties handling mathematical symbols. ST3 observed, *"It can be difficult to type in symbols and sometimes it cannot process symbols properly, which makes it difficult to use for mathematical subjects."*

The free version of ChatGPT was criticized for offering less comprehensive responses compared to the paid versions, which participants viewed as a financial barrier to accessing the full potential of AI tools. The phone interview with the 2018 student teacher also reflected concerns about over-reliance on AI, with the student cautioning, *"The application restricts some learners because the AI does most of the work for them, rather than the student doing it themselves."* Participants emphasized that excessive reliance on ChatGPT could hinder critical thinking and conceptual understanding of Mathematics. As ST1 explained, *"We don't usually get to know the information in the answered assignments. If the same question comes in a test, you find that a person is failing to answer."* ST6 added that ChatGPT often skips steps in

mathematical solutions, which can mislead students and undermine their engagement.

➤ *Impact on Conceptual Understanding of Mathematics*

Both the focus group and phone interview revealed a critical tension between the efficiency of ChatGPT and its impact on conceptual understanding. While ChatGPT aids in solving problems quickly, participants noted that it does not always promote deeper learning or active engagement with the material. ST4 remarked, “*The mind of actually trying to think and find solutions is not there,*” pointing to the potential erosion of problem-solving skills. The phone interview further supported this concern, with the 2018 student teacher reflecting, “As a student, you should acquire knowledge by researching and learning more about the task at hand.” This emphasizes the need for balanced use of AI tools to avoid passive learning and foster meaningful engagement with mathematical concepts.

➤ *Suggestions for Improvement*

To address these challenges, participants offered strategies to enhance the integration of AI tools such as ChatGPT into learning and teaching of Mathematics. ST1 emphasized the importance of incorporating face-to-face assessments, such as quizzes, projects and presentations, to reduce over-reliance on AI and ensure deeper understanding. As ST1 stated, “*AI has come to stay, so what can help is normalizing face-to-face contact for assessing students’ understanding.*” ST5 recommended using ChatGPT as a supplementary study tool rather than a primary resource for completing assignments. ST3 suggested that educational institutions adopt reliable AI tools and provide guidance to help students use them effectively while maintaining critical thinking and mathematical problem-solving skills.

VII. DISCUSSION

The quantitative analysis demonstrated that both cohorts achieved better results in assignments than in tests, with the 2024 cohort outperforming the 2018 cohort in assignments. The higher mean assignment score ($M = 90$) for the 2024 cohort compared to the 2018 cohort ($M = 82$) suggest that access to ChatGPT provided significant advantages. As corroborated by focus group participants, ChatGPT facilitated efficient completion of assignments, enhanced problem-solving through multiple methods, and simplified difficult mathematical tasks. These findings align with Ellis and Slade (2023), who highlighted the potential of ChatGPT in aiding mathematical problem-solving and improving efficiency in academic tasks. However, the test results revealed a contrasting trend: the 2018 cohort ($M = 62$) significantly outperformed the 2024 cohort ($M = 43$). This disparity suggests that while ChatGPT effectively supports assignments, it might inadvertently hinder conceptual understanding and knowledge retention. Focus group discussions revealed over-reliance on ChatGPT for assignments, leading to weaker test

performance. Participants noted that there is limited transfer of knowledge when AI is used solely as a task completion tool. This observation aligns with Mohamed et al. (2022), who cautioned against the potential for AI to impede critical thinking if over-relied upon without active engagement. Similarly, Cognitive Load Theory looks at ChatGPT as an important tool in lowering the intrinsic load inherent in mathematical concepts. This is likely, through the provision of detailed feedback and efficient search for information. On the downside over dependency on ChatGPT to lowers students’ mental effort (germane load) which is key in the formation of schemas and retention of concepts (Sweller, 2011).

The focus group discussions revealed the perceived benefits and challenges of ChatGPT. Participants emphasized its utility in improving academic efficiency, providing multiple solution methods, and assisting with formal writing tasks. However, challenges such as limited interaction capabilities, issues with mathematical symbols, and concerns about inconsistent responses were frequently cited. Notably, students expressed worries about diminished critical thinking. These concerns are supported by Pardos and Bhandari (2024), who noted that while ChatGPT can enhance learning gains in specific contexts, its effectiveness depends on how it is used. This is in line with the core constructs of the cognitive load theory which emphasizes the importance of using tools that can help scaffold and support learning. Henceforth, when ChatGPT is utilized as a learning tool it has the potential to enhance learners’ conceptual understanding of mathematics (Bai, et al, 2023). In contrast, findings from the 2018 cohort revealed a different learning approach. Without access to ChatGPT, students relied heavily on independent research, collaboration, and library resources, which fostered deeper engagement with course material. This method likely contributed to the cohort’s stronger test performance, as active learning is well-documented to enhance comprehension and retention (Malambo, Kazika & Phiri, 2023; Gouia-Zarrad & Gunn, 2024).

The findings present the dual-edged nature of AI in education. While ChatGPT offers opportunities to enhance assignment performance, it risks undermining deeper learning if not used judiciously. The contrasting results between assignments and tests reveal a critical need for balanced integration of AI tools in mathematics education. Students should be encouraged to use ChatGPT as a supplementary tool rather than a primary source for completing tasks. As one focus group participant suggested, incorporating face-to-face assessments such as quizzes and presentations could mitigate over-reliance on AI and foster conceptual understanding. The findings also align with broader literature showing the transformative potential of AI in mathematics education. According to Mohamed et al. (2022), AI can mimic human intelligence to provide tailored support, and studies such as Ellis and Slade (2023) affirm its capability to generate

learning gains. However, effective integration requires addressing limitations and promoting active learning strategies, as highlighted in this study.

VIII. CONCLUSION

The study assessed the impact of ChatGPT on conceptual understanding in mathematics education among student teachers at Mansa College of Education. The findings show that students with access to ChatGPT performed better in assignments than those without access which reflected its ability to enhance efficiency and quality of work. ChatGPT helped students complete tasks more quickly, provided multiple ways to solve problems, and simplified complex mathematical concepts. These benefits contributed to the observed improvement in assignment outcomes, highlighting the potential of ChatGPT to support academic tasks effectively. However, the test results presented a different trend. Students without access to ChatGPT performed better on tests, indicating a stronger retention of knowledge and better conceptual understanding. This suggests that while ChatGPT helped with assignments, it might not have supported deeper learning. Focus group discussions revealed that students who relied heavily on ChatGPT for assignments often did so without fully engaging with the underlying concepts. As a result, the transfer of knowledge from assignments to tests was limited, affecting their ability to solve problems independently. While ChatGPT provided useful opportunities for improving efficiency and offering different problem-solving methods, its limitations were also clear. Students reported difficulties with mathematical symbols, inconsistent responses, and concerns over reduced critical thinking. Many participants felt that relying too much on ChatGPT made them less able to think critically and solve problems on their own. The findings emphasize the mixed role of AI in mathematics education. ChatGPT offers clear advantages in assignment performance but can limit deeper understanding if not used properly. Teaching and learning practices should focus on balancing the use of AI with strategies that promote active learning, such as face-to-face assessments, collaborative problem-solving, projects, presentations and exploring concepts more thoroughly. These approaches can help reduce over-reliance on ChatGPT and encourage more meaningful learning. Therefore, while ChatGPT has the potential to transform mathematics education, it needs to be integrated thoughtfully. Encouraging students to use ChatGPT as a supplement rather than the main tool for completing tasks can help maximize its benefits while minimizing its drawbacks. With the right guidance, ChatGPT can be a valuable resource for enhancing both efficiency and conceptual understanding in mathematics education.

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