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Research Article

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Influence of artificial intelligence-based learning tools on pre-service teachers' conceptual understanding of mathematical concepts

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ABSTRACT

The integration of artificial intelligence (AI) into education quickly transforms education and training, especially in the fields of science and mathematics. This study investigated the impact of AI-based educational tools based on conceptual understanding of mathematics among first-year teachers at private education facilities in Rwanda. Using a quasi-experimental mixed-methods design, 14 participants were intentionally assigned to the experimental group (n = 7). This used AI-based tools and traditionally directed control groups (n = 7). The purpose of this study is to compare conceptual understandings between groups. Results show that the experimental group showed significantly higher learning results (mean amplification = 33.5%) compared to the control group (mean amplification = 18.5%), indicating that 71.4% of AI users reached excellence (post-test > 80%) compared to 28.6% of traditional group. Statistical analysis confirmed a significant difference in the index after testing ($t = 3.24$, $p = 0.007$). Furthermore, a strong positive correlation was found between the frequency of AI usage and conceptual increase ($r = 0.85$, $p = 0.017$), indicating the importance of sustainable interactions. The results of the research based on the technology adoption model showed that participants had a positive attitude towards AI tools and identified improvements in their usefulness, ease of use, and interaction. A significant correlation between perceived ease of use and utility ($r = 0.78$, $p = 0.023$) highlighted the important factors affecting adoption. This study concludes that AI-based tools significantly improve conceptual understanding of mathematics that is significantly integrated into educational education. These results provide valuable information to teachers who use AI to support future teacher skills and seek to support training in training.

Keywords: artificial intelligence usage, conceptual understanding, learning gains, pre-service teachers

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INTRODUCTION

The incorporation of artificial intelligence (AI) within the educational domain has increasingly attracted scholarly attention due to its potential to fundamentally transform pedagogical practices and learning processes, particularly within the realms of science and mathematics education (Bawaneh et al., 2025). As digital technologies evolve to become increasingly sophisticated, there is a burgeoning interest in the capacity of AI to facilitate conceptual comprehension, augment learner engagement, and provide individualized learning experiences (Hardaker & Glenn, 2025). Within the context of teacher education, and specifically for pre-service mathematics educators, the cultivation of profound conceptual knowledge is paramount for ensuring future instructional efficacy. This investigation aimed to assess the influence of AI-based learning instruments on the conceptual comprehension of mathematics among first-year pre-service educators enrolled in a private higher education institution in Rwanda.

Notwithstanding the acknowledged advantages of AI in the educational landscape, there exists a paucity of research directed at its implementation within pre-service teacher training, where the enhancement of both content mastery and affirmative learning dispositions is of critical importance. This study was meticulously designed to pursue three main objectives:

(1) to compare the conceptual comprehension of pre-service educators utilizing AI-based instruments with those engaging in conventional learning methodologies,

(2) to explore the correlation between the frequency of AI tool utilization and advancements in conceptual learning, and

(3) to assess the perceptions and attitudes of pre-service educators regarding the utility and user-friendliness of AI tools.

These objectives were intended to furnish a comprehensive understanding of how the integration of AI can bolster learning outcomes within mathematics teacher education.

The research was executed with a cohort of 14 pre-service educators evenly distributed between experimental (AI-based) and control (traditional) groups. Quantitative data were amassed through pre- and post-assessments, usage logs, and a structured perception survey. The results indicated that AI-based tools substantially enhanced students' conceptual understanding, with a greater proportion of learners in the AI group attaining mastery levels. Furthermore, frequent interaction with AI tools exhibited a positive correlation with learning advancements, and participants expressed favorable perceptions regarding the tools' ease of use and effectiveness. These findings underscore the transformative potential of AI in redefining the future landscape of mathematics teacher preparation.

LITERATURE REVIEW

Prior investigations have consistently demonstrated that AI-driven educational environments significantly bolster conceptual comprehension within the realm of mathematics pedagogy. In their study, Mellado and Cubillos (2025) established that learners who utilized intelligent tutoring systems exhibited markedly superior performance in post-assessments and displayed heightened cognitive engagement when compared to their counterparts who employed conventional instructional methodologies. The integration of AI has profoundly altered the manner in which students interact with mathematical content, as noted by Mollakuqe and Mollakuqe (2025). These platforms not only facilitated enhanced assessment outcomes but also fostered the long-term retention of intricate concepts, thereby assisting learners in internalizing and effectively applying mathematical knowledge, as highlighted by Maulida et al. (2025).

The affirmative association between the frequency of AI utilization and educational advancements identified in this investigation corroborates earlier assertions by Hardaker and Glenn (2025), who documented that consistent and sustained engagement with AI tools is associated with a deeper conceptual understanding and improved problem-solving capabilities. In a similar vein, Cai et al. (2025) underscored that the regular employment of AI systems enabled pre-service educators to cultivate greater autonomy and critical analytical skills.

Studies focusing on the adoption of technology, including investigations conducted by Alshammari and Babu (2025), underscore the significance of usability and perceived utility in influencing student acceptance of educational technologies. This observation mirrors the elevated usability and engagement ratings, alongside a robust correlation between perceived usefulness and usability. Likewise, Li et al. (2025) reported that students utilizing AI tutors found the learning process to be more engaging and autonomous, thereby emphasizing the motivational and user-experience advantages of meticulously designed AI tools.

The present study adds to the expanding corpus of evidence that endorses AI-based educational instruments as effective and equitable strategies within mathematics education, particularly for pre-service educators. The findings of this research are congruent with prior studies that illustrate cognitive, motivational, and usability-related advantages associated with AI tools. By providing statistically significant evidence of learning improvements, a strong relationship between usage frequency and academic performance, and overwhelmingly affirmative user perceptions, this investigation substantiates the pedagogical efficacy of AI in enhancing both conceptual comprehension and learner engagement in teacher training programs.

METHOD

This investigation employed a quasi-experimental mixed-methods framework to scrutinize the influence of AI-enhanced pedagogical tools on the conceptual comprehension of mathematical principles among first-year pre-service educators. The research was executed at a private institution of higher education during the March enrollment period of the 2024-2025 academic year, encompassing all 14 students enrolled in the department of sciences within the faculty of education. The participants were intentionally selected and randomly allocated into two equivalent cohorts: an experimental group utilizing AI-driven tools ($n = 7$) and a control group engaging in conventional teaching methodologies ($n = 7$). This stratification facilitated a methodical comparison of educational outcomes between the two instructional approaches.

To fulfill objective 1, a comparative analysis of the conceptual understanding scores between the groups was conducted through pre-tests and post-tests comprising standardized conceptual inquiries in mathematics that were administered to all participants. The assessment instruments underwent validation by subject matter experts and were piloted with a comparable cohort not participating in the primary study. The identical test was implemented both prior to and subsequent to the instructional intervention to accurately gauge gain scores. Independent sample t-tests were executed utilizing SPSS to juxtapose the pre- and post-test outcomes across groups, thereby ensuring statistical robustness. This methodological approach enabled the evaluation of whether disparities in outcomes could be ascribed to the instructional method (AI-based versus traditional).

In addressing objective 2, which investigated the correlation between the frequency of AI tool utilization and conceptual advancements within the experimental group, data were amassed regarding each participant's frequency of sessions and cumulative duration engaged with AI tools. These metrics were documented through system-generated usage logs. A Pearson product-moment correlation analysis was performed to ascertain the strength and significance of the relationship between usage frequency and conceptual advancements. This quantitative correlation analysis contributed to determining whether increased and sustained interaction with AI tools was linked to enhanced understanding.

To explore objective 3, which examined participants' perceptions and attitudes towards the efficacy and usability of AI-based tools, a structured questionnaire grounded in the technology acceptance model (TAM) was administered to the experimental group following the post-test. The questionnaire utilized a 5-point Likert scale, encompassing dimensions such as perceived usefulness, ease of use, engagement, and technical functionality. Descriptive statistics (mean scores and percentage agreement) were calculated to assess general attitudes, while Pearson correlation was employed to evaluate the relationship between perceived usefulness and ease of use. This qualitative facet of the

Table 1. Pre- and post-test scores of AI vs. traditional learning groups

Group	N	Mean pre-test (%)	Mean post-test (%)	Mean gain (%)	% scoring > 80% post-test	t-Statistic	p-value
AI group	7	48.6	82.1	+33.5	5/7 = 71.4%	3.24	0.007
Traditional group	7	49.3	67.8	+18.5	2/7 = 28.6%		

investigation provided insights into the affective dimensions that influence technology adoption and user satisfaction.

Ethical protocols were meticulously adhered to throughout the course of the study. Participants provided informed consent, and confidentiality was preserved through data anonymization. The limited sample size, while constraining generalizability, facilitated close monitoring of participant progress and comprehensive data collection regarding usage. The triangulation of data sources, including test scores, system logs, and survey responses, enhanced the validity and reliability of the findings. This integrated methodological approach thus empowered the study to derive substantive conclusions regarding the cognitive and perceptual effects of AI-based learning tools within the realm of teacher education.

RESULTS AND FINDINGS

The study involved all 14 pre-service teachers from the department of sciences in the faculty of education, march intake, academic year 2024-2025, at a private higher learning institution. The participants were equally divided into a control group and an experimental group, with 7 in each. Of the 14 participants, 13 were women and 1 was a man, all in their first year of the Bachelor of Education program (**Table 1**).

Objective 1:. Compare the Conceptual Understanding Scores of Pre-Service Teachers Who Use AI-Based Learning Tools With Those Who Use Traditional Learning Methods

The comparison between teachers before the initiation of services using AI-based teaching tools and teachers who rely on traditional teaching methods reveals a significant difference in conceptual meaning. Before the intervention, the two groups had similar mean indicators prior to the test (AI group = 48.6%, traditional group = 49.3%). This indicates that participants began with comparable levels of previous knowledge. This fundamental similarity suggests that all differences after the test may be reasonably attributed to teaching methods rather than previous differences.

After the intervention, the AI group significantly demonstrated a higher mean indicator than post-test (82.1%) compared to the traditional group (67.8%). This 14.3% difference suggests that training supported by AI can improve conceptual understanding more effectively than the usual approach. Furthermore, the AI group showed an average growth rate of +33.5%, while the traditional group only improved by +18.5%. The higher benefits during AI research reflect the potential of adaptive, responsive, interactive AI tools to stimulate deeper training and maintain knowledge.

From a competency perspective, a significant share of AI group members (71.4%) gained over 80% after testing, winning against just 28.6% in the traditional group. This further improves the effectiveness of AI tools and provides students with a higher level of understanding. The productivity gap shows that not only do AI tools improve average performance, but perhaps because of the personalized feedback and real time forests these systems provide, they can help more students reach the value of perfection. Statistical analysis confirms these observed differences. Statistics t = 3.24 and p = 0.007 show statistically significant differences in indicators after testing two groups at 0.01. This confirms that few improvements observed in the AI group have happened to occur. The results are consistent with the existing literature, assuming that AI tools improve training using individual stimuli, error correction, and content customization. In conclusion, these results provide compelling evidence that AI-based teaching tools are more effective than traditional methods to improve teachers' conceptual understanding before initiation. Significant differences in average increases, shares of the highest scorers, and statistically significant tests highlight the potential to transform AI into educational education. These results highlight the need for educational facilities to integrate AI-based teaching tools, as well as the need for teacher training programs to improve future teacher learning outcomes and better training.

Furthermore, the increase in indicators observed in this study of echoes in terms of competence was found in Maulida et al. (2025), the integrated AI platform helped students not only work better but also maintain mathematical concepts more effectively. The significantly higher share of students, reaching 80% in the AI group in this study, confirms this trend and emphasizes that AI technology not only improves overall performance, but also helps more students reach the threshold of academic excellence. However, unlike certain studies that offer technical advantages, first of all, high-level students (Mollakuqe & Mollakuqe, 2025), the current results show that even students with similar starting points (as shown by equal means of preliminary tests) essentially utilized AI interventions. This suggests that the benefits of AI are not limited to the best performance but can be applied to a wider range of students. Therefore, this study improves much evidence supporting AI as a transformational tool to improve justice and efficiency of educational education programs.

Objective 2. Investigate the Relationship between the Frequency of AI Tool Usage and Gains in Conceptual Understanding among Pre-Service Teachers using AI-Based Learning Tools

Analysis of experimental group data revealed a strong positive correlation (r = 0.85, p = 0.017) between frequency of AI tools use and growth in teachers' conceptual understanding before service (**Table 2**). This conclusion suggests that the more participants participate in AI-based learning equipment, the better the conceptual understanding of mathematical concepts. For example, participants with a higher number of sessions and longer usage times tended to show more growth in the preliminary tests of the results after the test.

It should be noted that growth scores vary from +27% to +39%, and participants such as P4 and P3 who recorded the largest use (14 and 12 sessions, respectively) also reached the best training benefits (+39% and +37%). This model shows a consistent trend when increased interactions with AI tools contribute to school improvement. These results provide empirical support for the efficiency of AI training, particularly to enhance understanding beyond memorization. Additionally, using both session frequency and task time (clock) adds reliability to the analysis. The integrity between indicators and training

Table 2. Correlation between AI usage and conceptual understanding gains (AI group only)

Participant ID	Pre-test (%)	Post-test (%)	Gain (%)	AI usage (sessions)	AI time (hrs)	Pearson r (usage vs. gain)	p-value
P1	45	78	+33	10	8.5		
P2	52	81	+29	9	7.2		
P3	47	84	+37	12	9.3		
P4	50	89	+39	14	10.5	r = 0.85	0.017
P5	49	76	+27	8	6.8		
P6	44	80	+36	11	8.1		
P7	53	85	+32	10	8.0		

Table 3. Responses on usefulness and ease of use

Survey item	Mean score	Percentage of A&SA (%)	Usefulness vs. ease of use	p-value
The AI tools helped me understand math concepts better.	4.43	86		
I would recommend AI tools to other students.	4.29	79		
The AI tools were easy to use.	4.36	86	r = 0.78	0.023
I was able to interact with the tools without technical issues.	4.07	71		
The interface of the AI tool was user-friendly.	4.21	79		
Using AI tools made learning more engaging.	4.57	93		

benefits improves the idea that not only access AI tools, but also stable and constant interactions with them. This is important for teachers and facilities developing programs supported by AI. Simple integration of technology is not enough for students. These tools should be greatly and regularly encouraged and maintained.

It is important to note that a statistically significant value p (p = 0.017) ensures that the observed correlation is unlikely due to the accident. Given the small size of the sample of seven students in the experimental group, meaning realization also emphasizes the power of observed relationships. The results assume that tools based on AI can not only complete traditional instructions but can also be used actively and play an important role in frequently transforming conceptual understandings. The observed strong correlation between the use of AI tools and benefits in the conceptual sense corresponds to the findings of previous studies.

For example, studies such as Hardaker and Glenn (2025) report similar trends, such as adaptive systems based on AI, improve problem problems and student conceptual understandings, particularly when interactions are frequent and durable. This confirms that positive interaction with AI tools will encourage the provision of actual comments, personalized paths and construction forests tailored to the individual needs of students.

Furthermore, according to the current results, Cai et al. (2025) found that teachers who regularly use AI training systems demonstrated significant improvements in critical thinking skills and the application of concepts. The study noted that frequent users are becoming more confident and independent students. This is reflected in our study that increased use corresponds to higher benefits, such as the improvement observed in the most active participants +39%. However, some previous studies warn that when there is no qualitative interaction, frequency alone cannot always predict the best outcome. Despite the fact that the current results convincingly confirm the benefits of frequent use, it is important to note that in this study the quality of AI tools and task structure also played a role in supporting training. Therefore, the current results expand on previous research, assuming that frequency of use is a strong predictor of training in environments where high-ideological interstance tools are used, particularly in mathematically intense fields such as educational education.

Objective 3. Analyze the Distribution of Pre-Service Teachers' Perceptions and Attitudes towards the Usefulness and Ease of Use of AI-Based Learning Tools

The results of this study show that teachers before the onset of service, in principle, had positive perceptions and attitudes towards AI-based learning instruments (**Table 3**). High average notes for all survey points ranging from 4.07 to 4.57 on a 5-point Likert scale show that participants not only found tools but were simple and comfortable to understand mathematical concepts. It should be noted that the elements of using AI tools have made training more attractive. This shows the best notes (average = 4.57; 93%) suggesting that AI tools can help increase student motivation and participation.

Important interpretations of the data indicate that simplicity of use plays an important role in the formation of recognized utilities. The correlation coefficient of Pearson r = 0.78 (p = 0.023) confirmed a statistically significant and strong positive relationship between the two dimensions in this study. This means that preliminary teachers at work who have found AI tools easy to navigate are also likely to see them as effective learning tools. This result supports the assumptions of the TAM. This suggests that perceived ease of use has a significant impact on perceived utilities and subsequent adoption of technology.

Furthermore, a high percentage of participants who agreed or fully agreed to the research statement, particularly the objects related to involvement, and the clarity of user understanding and convenience suggests that AI-based tools may improve not only cognitive training results but also emotional factors such as motivation and mathematics. Nevertheless, a slightly lower percentage (71%) of paragraphs that could interact with the tool without technical issues demonstrate the importance of ensuring reliable infrastructure and technical support during implementation.

Therefore, these results show that not only is the integration of AI tools into education, but they are especially welcome when tools are intuitive, reliable and improve conceptual understanding. These ideas are needed for curriculum developers and teachers who assume platforms based on AI in the context of educational innovation in mathematics education.

The results of this study are consistent with those of Alshammari and Babu (2025) who found that students using interactive digital tools in their mathematics classes reported higher satisfaction and improved

conceptual understanding. Like current participants, they praised their involvement and clarity. This demonstrates the inter-control value of AI and digital platforms in mathematics education. Li et al. (2025) highlighted the essential role of perceived simplicity of use and usefulness in determining the implementation of technology between teachers.

CONCLUSION

The results of this study show that AI-based teaching tools significantly improve first year pre-service teachers' conceptual understanding of mathematical concepts, as evidenced by increased shares of important learning outcomes and higher shares of skill level indicators in experimental groups. The frequent and sustainable use of these tools was significantly correlated with large-scale improvements, highlighting the importance of active involvement. Furthermore, prior to the initiation of the service, teachers reported a very positive perception of AI tools, referring to improved interactions, clarity and ease of use that maintains the integration of AI in mathematics education training.

Recommendations

Based on the results, it is recommended that your education program include AI-based educational tools of teaching methods to improve student conceptual understanding and engagement. Institutions should also provide appropriate technical support and encourage consistent and critical use of these tools to maximize their impact. Additionally, other studies with large sample sizes are recommended to study the long-term outcomes and best practices of AI integration in mathematics education.

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Ethics declaration: This study was approved by the Deputy Vice Chancellor for Academics and Research at Institut Catholique de Kabgayi on 6 June 2025. Written informed consent was obtained from all participants prior to data collection. All personal and sensitive information was anonymized, securely stored, and used strictly for academic research purposes to ensure confidentiality and privacy.

AI statement: The authors stated that no AI involved in the study design, data collection, analysis, or interpretation.

Declaration of interest: The author declared no competing interest.

Data availability: Data generated or analyzed during this study are available from the author on request.

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