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Influence of conversational agent on students' attitude toward mathematics

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Abstract

Purpose – There exists a phenomenon called students' negative attitude toward mathematics, leading to a decline in students' performance in mathematics and influencing their decisions to refrain from pursuing Science, Technology, Engineering and Mathematics (STEM) majors and careers. Studies show that using technology in education can reduce anxiety toward mathematics by increasing students' motivation to explore and appreciate mathematics. Conversational agents (CAs), automated software that interacts with users via natural language, can be used in education to support teaching and learning. Unfortunately, despite its nearly 60-year history, the application of this technology in the education domain is still scarce. This study aims to examine the effectiveness of integrating CA on students' attitude toward mathematics.

Design/methodology/approach – To compare the impact of different teaching methods, students were randomly divided into two groups: a control group receiving only traditional classroom instruction and an experimental group receiving traditional instruction combined with interaction with a CA. After that, they participated in a five-point Likert scale questionnaire on attitude toward mathematics.

Findings – The findings revealed that integrating CA in mathematics teaching and learning significantly reduced experimental students' anxiety toward mathematics while there was no improvement shown in the importance of mathematics.

Originality/value – The integration of features such as experiential learning, social dialogue, affective learning and scaffolding makes this CA a comprehensive tool for promoting personalized and engaging learning experiences among students thus reducing students' anxiety and increasing their overall confidence toward mathematics.

Keywords Attitude toward mathematics, Conversational agent, Traditional teaching, Technology in education, Mathematics anxiety

Paper type Research paper

Introduction

Far from being simply an academic hurdle, mathematics serves as a crucial stepping stone for higher education success and future careers. By instilling essential problem-solving skills applicable across diverse professional fields, math empowers students to thrive in college and beyond. Consequently, a robust foundation in mathematics is frequently a prerequisite for admission to highly competitive colleges and universities (Nanayakkara and Peiris, 2017). However, students' difficulties with mathematics can often lead to failure in the subject, which

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can in turn cause them to fall behind in their studies or even drop out altogether. Mathematics is often perceived as challenging, leading to the dropout of numerous students from STEM courses, consequently limiting access to opportunities in scientific, engineering and technological fields (Schoenfeld, 2019). Continuous struggles in mathematics can lead a student to experience demotivation and overwhelming anxiety. This anxiety can result in reduced self-confidence, a fear of failure and a pessimistic outlook on the process of learning mathematics (Pizzie and Kraemer, 2017).

According to Tan *et al*. (2022), open-ended discussions between teachers and students can significantly improve learning outcomes. However, challenges arise in large or short class sessions. Factors such as the lecture session's size and time constraints make effective learning and engagement difficult. Introverted students may avoid clarifying doubts in class, opting to meet the lecturer privately. Consequently, they struggle to focus in class and may underperform in mathematical assessments.

The research highlights the positive impact of technology on students' engagement in mathematics. It emphasizes that technology not only encourages active participation but also facilitates peer interaction, instant feedback and overall support for students. Additionally, the use of technology helps reduce mathematics anxiety by motivating students to explore and enjoy the subject rather than feeling overwhelmed (Park and Choi, 2020). The integration of technology, particularly conversational agents (CAs), creates a positive and comfortable learning environment, further diminishing anxiety and tension related to solving complex mathematics problems. Moreover, increased participation of students with the agent within the learning system will enhance their learning experiences, leading to positive emotions among students.

Students' journeys in mathematics are shaped by a constant dance between success and failure, shaping their evolving attitudes toward the subject. These attitudes can swing between two emotional poles: positivity, characterized by a favorable temperament and engagement and negativity, marked by disinterest and apprehension. Each success fuels confidence and motivation, nourishing a positive outlook, while setbacks can breed frustration and anxiety, tilting the balance toward negativity. This dynamic interplay between achievement and emotion underscores the importance of fostering a supportive learning environment that celebrates progress and offers strategies to overcome challenges, ultimately guiding students toward a positive and enriching mathematical experience (Hannula, 2019; Pekrun, 2020).

The main purpose of this study is to examine the effectiveness of integrating CA on students' attitude toward mathematics. Educational landscapes are evolving alongside technology, with CAs emerging as a captivating area of exploration. This study emphasizes the importance of integrating innovative digital tools like these agents to enhance student learning experiences. By embracing such technologies and experimenting with diverse instructional approaches, educational institutions can unlock the potential for delivering high-quality education and empowering students on their journeys toward academic success.

Literature review

Attitude toward mathematics

Attitude encompasses an individual's emotions, thoughts and actions in reaction to a specific situation or object (Cherry, 2023). Just like any other object, mathematics can evoke a wide spectrum of emotions, including admiration, disdain, fear or affection. These varied emotional responses are crucial in shaping how students interact with and approach the subject. Positive attitudes toward mathematics are often associated with a more profound engagement and better performance in the subject. Students who view mathematics positively are likely to approach it with curiosity and enthusiasm, leading to greater persistence and resilience when faced with challenging problems. Positive attitudes generally contribute to more favorable life outcomes, such as improved academic performance and a stronger appreciation for the subject's role in various aspects of life. Conversely, negative attitudes can lead to avoidance and disengagement, impacting students' learning experiences and outcomes significantly. A negative mindset toward mathematics can hinder students' ability to tackle complex problems, reduce their willingness to seek help and decrease their overall academic motivation (Zan and Di Martino, 2007). Hence, it is logical to infer that one's attitude toward a particular subject, such as mathematics, can have a profound impact on the depth of their understanding and success in that area. A positive mindset can facilitate a more effective learning process, making complex concepts more accessible and enjoyable.

Students often face numerous challenges related to mathematics, which can significantly influence their attitudes toward the subject. Difficulties in grasping mathematical concepts, solving complex problems and overcoming a fear of mathematics can lead to a negative perception of the subject. Mathematics anxiety, which arises from negative or embarrassing past experiences, often exacerbates these challenges. Such anxiety can manifest as a deep-seated belief that mathematics is too difficult, leading students to withdraw from the subject. This negative perception can result in students perceiving mathematics as tedious and irrelevant to their daily lives. For instance, research has shown that many students view mathematics as a challenging and boring subject, with little connection to practical applications or personal interests (Gunduz and Saracbasi, 2022). Chen *et al.* (2018) similarly found that students' attitudes toward mathematics are often characterized by negativity, influenced by a perceived lack of real-world relevance. The emotional and cognitive components of students' attitudes toward mathematics are also affected by their interactions with instructors. For example, students who encounter strict or unsympathetic teaching styles may develop a heightened sense of anxiety and reluctance toward the subject (Li *et al.*, 2020).

The perception of mathematics involves a complex interplay of cognitive, emotional and behavioral components (Titrek and Özkan, 2016). This multifaceted framework suggests that attitudes toward mathematics cannot be fully understood through a single dimension but rather through a combination of cognitive beliefs, emotional responses and behavioral tendencies. For example, a study involving 1,496 Italian students from grade 2 to grade 13 highlighted three significant dimensions: students' perspectives on mathematics, their emotional dispositions and their perceived competence in the subject (Vecchione *et al.*, 2020). These dimensions collectively shape how students approach and engage with mathematics. Additionally, the Trends in International Mathematics and Science Study (TIMSS) researchers employ three dimensions to assess students' attitudes, which include their excitement for mathematics, their confidence in their mathematical abilities and their perceived value of the subject (Mullis *et al.*, 2020). This multidimensional understanding underscores the need to address various aspects of students' attitudes to foster a more positive and comprehensive engagement with mathematics. A well-rounded approach to understanding these attitudes can provide valuable insights into how to better support students in developing a more favorable view of mathematics, ultimately leading to improved academic performance and a more enduring appreciation for the subject.

In summary, students' attitudes toward mathematics are influenced by a range of factors, including their emotional responses, cognitive beliefs and behavioral tendencies. These attitudes play a critical role in determining their engagement with the subject and their overall academic success. Understanding the multifaceted nature of these attitudes is essential for educators aiming to foster a more positive and effective learning experience in mathematics. By addressing both positive and negative aspects of students' attitudes, educators can better support students in overcoming challenges and achieving success in mathematics.

Measuring attitudes

The measurement of attitudes toward mathematics is crucial in research, and various methods are employed for this purpose. Common approaches include self-report measures, behavioral measures, psychological measures and implicit measures (Schwarz, 2008). Self-report measures, such as surveys and questionnaires, are popular and often use Likert scales to gauge respondents' agreement or disagreement with statements about mathematics. These instruments provide valuable insights into individuals' explicit attitudes and perceptions. Behavioral measures track activities like time spent on math-related tasks or seeking opportunities to practice, offering an indirect way to assess engagement. Psychological measures, such as heart rate or skin conductance, can indicate physiological responses linked to attitudes in situations where respondents may not be willing or able to express their feelings directly. Implicit measures, exemplified by the implicit association test (IAT), assess the strength of associations between mathematics and favorable or unfavorable evaluations, providing a nuanced understanding of underlying attitudes that may not be consciously recognized.

Evaluating students' attitudes toward mathematics is challenging because attitudes cannot be directly observed. Critics may target both the instruments used and the concept that attitude measurement is necessary, arguing that attitudes are inherently subjective and complex to quantify. The conventional approach linking attitude to mathematical success relies on measuring attitude as a crucial step, yet creating precise and reliable instruments for measurement remains difficult. Some success is achieved by using instruments that test various components of attitude. For example, Aiken (2000) used enjoyment and value measures to capture specific aspects of attitudes, Fennema and Sherman (1999) developed a nine-scale instrument considering factors like confidence and motivation, and Tapia and Marsh (2002) designed a four-factor questionnaire addressing different dimensions of attitude. Despite these challenges, many studies rely on Likert scale-based questionnaires (self-report measures) to assess multiple facets of attitudes toward mathematics. These tools remain widely used due to their ease of administration and ability to capture a range of attitude components, despite ongoing discussions about their limitations and the need for complementary methods.

Conversational agent

CAs refer to software programs designed to replicate human conversation, engaging with users through natural language interactions. These agents, also known as chatbots, interactive agents or artificial conversation entities, operate as dialogue systems capable of comprehending natural language and generating human-like responses (DeepAI, 2019). They are widely employed as chatbots on the internet or personal assistants on mobile devices, utilizing computational linguistic techniques to understand and respond to users in a manner resembling human conversation. As CAs become more advanced, their ability to simulate human-like dialogue has improved, allowing them to engage users in increasingly meaningful and contextually relevant interactions. This evolution includes incorporating advanced algorithms and richer datasets, enabling more nuanced and accurate responses that can better cater to user needs.

CAs primarily rely on natural language processing (NLP) and machine learning (ML) technologies. NLP enables the agent to grasp the meaning of human language, parsing complex sentences and understanding context, while ML facilitates learning from user interactions. This learning process involves analyzing vast amounts of data to identify patterns and improve response accuracy, leading to increased sophistication over time and a better understanding of user needs and preferences (Vishnoi, 2020). Although chatbots were first developed in the 1960s and 1970s, it is the recent advancements in artificial intelligence, NLP and ML that have significantly propelled their widespread usage and functionality, making them more effective and versatile tools in various domains. Modern CAs integrate with various platforms and can handle multi-turn conversations, addressing complex queries with greater contextual awareness.

When examining the application of CAs in the educational domain, it is crucial to determine their suitable role within the learning environment. Chibber and Law (2019) suggest that educators can designate the role of CAs based on their preferences and educational goals, such as functioning as lecturers, tutors, mentors, peers or interactive game participants. The choice of role depends on the specific goals and teaching strategies of the educator as well as the needs of the students. Additionally, Chen *et al.* (2023) conducted a study to investigate the potential, advantages and limitations of CAs, as "intelligent student assistants" in higher education. The study aimed to evaluate how effectively these tools can teach non-technical students about technology, with the CA assuming the role of a tutor. This research highlighted the adaptability of CAs in providing tailored educational support, demonstrating their potential to enhance learning outcomes across various subjects. Moreover, the role of CAs can be dynamically adjusted based on student feedback and performance, ensuring that the educational support provided is both relevant and effective.

The use of CAs is widespread in various fields, but their adoption in education, particularly in mathematics education, is limited according to literature reviews. Despite the growing popularity of CAs, their integration into educational settings, especially in mathematics, is in the early stages of expansion (Wang *et al.*, 2021). This suggests potential for growth, emphasizing the need for further research and development in utilizing CAs as educational tools in mathematics education.

CAs can play a valuable role in educational settings due to their interactive nature, setting them apart from traditional e-learning systems. They offer an engaging and interactive mechanism for students, providing a more dynamic and personalized learning experience. By offering immediate feedback, addressing inquiries and supporting students throughout their learning journey, CAs provide personalized assistance and guidance that can significantly enhance the learning experience (Sridhar *et al.*, 2022). Additionally, CAs contribute to education by automating administrative tasks, facilitating rapid access to educational resources and saving time for both educators and students. This efficiency helps maximize students' learning potential and achievements by allowing more time to focus on complex problem-solving and critical thinking (Sharma *et al.*, 2022; Mohammed *et al.*, 2022). The reduction of repetitive administrative tasks through automation also allows educators to devote more time to personalized student engagement and curriculum development. According to Zhu *et al.* (2022), incorporating challenging questions into CAs has been shown to enhance students' mathematical confidence. As students advance to more complex questions, they have the opportunity to observe their own development and achievements, fostering a sense of fulfillment and bolstering their confidence in approaching mathematical challenges.

Furthermore, CAs can additionally elevate students' self-assurance by granting them greater control over their learning journey. Other studies have highlighted that those interactive tools, such as CAs, can maintain students' motivation and engagement by creating an enjoyable and comfortable learning environment. This approach enables students to absorb knowledge conveniently, reducing the likelihood of boredom and disengagement (Rooein, 2019; Chen *et al.*, 2020). Constructive feedback during the learning process is essential for improving performance and motivation. Using CAs as a feedback tool has a positive impact on task completion and engagement metrics, as students can inquire further about their assessments. The immediate solutions provided by CAs allow students to correct errors promptly and enhance their understanding of mathematical concepts, making them valuable assets in educational settings (Tsai and Hwang, 2021). Moreover, CAs' ability to analyze individual student progress allows for continuous adaptation of learning materials, ensuring that content remains relevant and challenging. This personalized feedback loop not only supports students in addressing immediate difficulties but also contributes to long-term academic growth and achievement. The continuous adaptation and real-time interaction provided by CAs make them a transformative tool in education, capable of addressing diverse learning needs and enhancing overall educational experiences.

Methodology

Experimental design

This study was conducted using a quasi-experimental design with convenience sampling. The study utilizes pre-existing groups formed when students enrolled in the mathematics subject. Due to administrative constraints on scheduling and venue setup, and to avoid disrupting classroom norms, pre-existing groups were used instead of randomly assigning students to experimental and control groups. Within these groups, students who were readily accessible and willing to participate were selected. A consent form was given to all students, and only those who agreed to participate were included in the study.

Participants

The targeted populations of this study consist of 230 students from Malaysia's private university undergraduate students who were majoring in Information Science and Technology. About 200 students participated in this study. Students were assigned to a willing lecturer who approved the study to be carried out on her students. The sample was diverse, including both female and male students from various ethnic backgrounds, such as Malay, Chinese, Indian and others. The sample also included both local and international students. The experimental group consisted of 115 students, while the control group included 85 students. Due to administrative restrictions and the need to avoid disrupting classroom norms, pre-existing groups were used instead of randomly assigning students, and students were asked to voluntarily choose the group, either control or experimental groups, to be joined in the study, resulting in unequal sample sizes. Quantitative research methodology was used to gather and analyze data related to students' attitude toward mathematics. The "Integration" topic was chosen for this study.

In this study, a sample size of 200 was utilized, exceeding the calculated minimum of 119 for a population of 230 (95% confidence level and 5% margin of error). While this sample size is statistically sound and improves reliability by reducing the margin of error to approximately 4.4%, a larger sample size would further enhance the generalizability of the findings. However, logistical constraints, including class size and resource availability, limited the feasibility of a larger sample. Thus, the current sample remains statistically valid and provides ample power for achieving the study's objectives (Thomas, 2020).

Material

A CA that was integrated into Facebook Messenger was developed for integration. This agent acted as a tutor role in this study. This agent was created by incorporating various elements, including affective learning, experiential learning, social dialogue and scaffolding. The CA breaks down learning content into clear, bite-sized pieces, promoting quick understanding and reducing overwhelming pressure and stress for the user. While addressing challenges, the agent inspired students by offering motivational content or messages to encourage them in the problem-solving journey. Moreover, the agent also provided succinct explanations on subtopics, examples and exercises, accompanied by step-by-step solutions. It incorporated constructive feedback and motivational quotes to enhance students' confidence in their learning journey. Additionally, students had the flexibility to attempt questions multiple times, irrespective of their initial incorrect responses.

Instrument

The mathematics attitude dimension is the instrument developed in this study to measure students' attitude toward mathematics. The questionnaires used in this study were adopted, adapted and self-designed. The instrument consists of 11 questions, each for a pre- and post-test that question students' perspectives on their attitude toward the learning of the mathematics syllabus "Integration" with a five-Likert scale. The questionnaire was divided into two dimensions: the importance of mathematics and anxiety toward mathematics. The concept of attitude dimensions was adapted from Tapia and Marsh's (2002) four-factor questionnaire.

Participants in the study were asked to sign a consent form before answering the questionnaire to confirm their agreement to participate in the study. Afterward, they were requested to share confidential general information, including age, gender, race and nationality. Experienced mathematics lecturers from the private university carefully examined and validated the questionnaire to guarantee the quality and suitability of the questions for the study. Additionally, the reliability of this instrument was assessed using the Statistical Package for the Social Sciences (SPSS) by computing Cronbach's alpha. The computed Cronbach's alpha was 0.921, which implies the instrument is excellent according to Amirrudin *et al*. (2021). The calculated Cronbach's alpha value for the instrument not only confirms its reliability but also suggests that the instrument exhibits internal consistency, indicating its reliability in measuring each variable. Table 1 displays the example of questions used in the mathematics attitude dimension questionnaire.

Research procedure

The study spanned a duration of five weeks and comprised three distinct stages. Initially, a pre-test was administered before students were introduced to the topic of "Integration" by the university lecturer. Prior to the pre-test, the researcher provided a briefing to the students explaining the study's purpose, and participants were required to sign a consent form to voluntarily partake in the test. Participation was entirely based on the students' choice, and both the control and experimental groups took part in the pre-test.

Moving to the second stage, a CA was developed and integrated into the teaching and learning process of the mathematics syllabus. Experimental group students were briefed on the purpose of the CA before its utilization for learning. Both groups received traditional teaching on the topic of "Integration" from the same lecturer, but only the experimental group had access to the CA. This intervention spanned a period of three weeks, during which the experimental group independently utilized the CA at their own pace outside of their curricular schedule at their convenient time and place.

In the final stage, a post-test was conducted upon the completion of the "Integration" topic. This stage took place in the last week of the study, and students from both groups participated in the post-test. Both groups were given a post-test on the mathematics attitude dimension to evaluate the effectiveness of the CA in improving students' attitude toward mathematics.

Data analysis

The quantitative data gathered from the mathematics performance test undergoes additional scrutiny through the application of the SPSS, a widely employed software for statistical analysis in social science research. An independent sample *t*-test was employed to analyze the data gathered from participants, aiming to investigate any noteworthy distinctions between the

Table 1. Example of questions in mathematics attitude dimension

Dimensions	Item
Importance of mathematics	Taking high school math courses would be beneficial regardless of my future plans
Anxiety towards mathematics	Learning mathematics makes me anxious

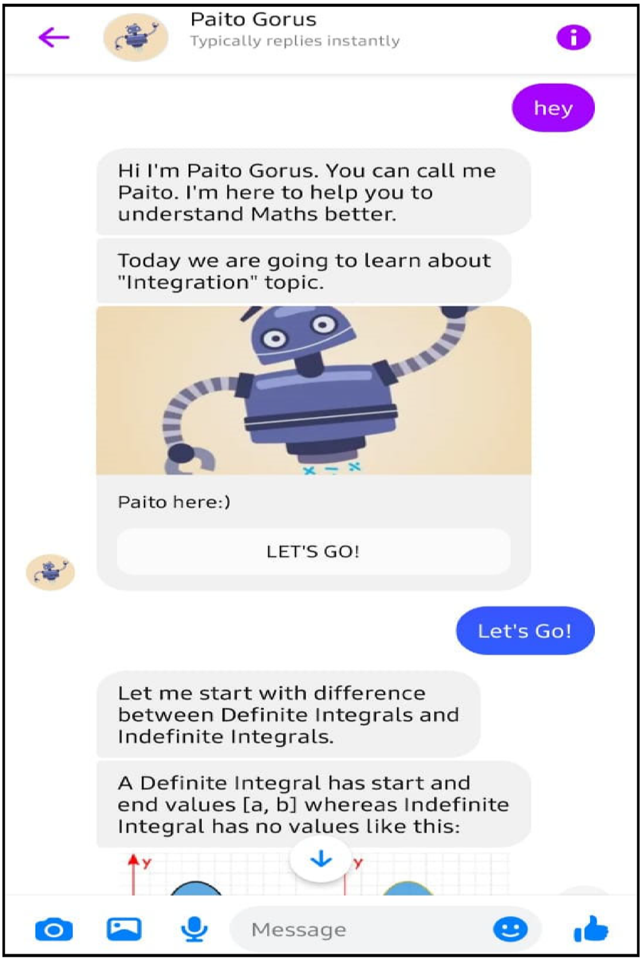
Source(s): Authors' own work

control and experimental groups in both the pre- and post-test phases. The collected data was analyzed using SPSS at a 5% significance level.

Conversational agent's prototype

The agent in this study is named as "Paito Gorus". Illustrated in Figure 1 is an overview of Paito Gorus's Facebook page. Students have the convenience of accessing this page from any location at any time. To initiate a conversation with Paito Gorus via Facebook Messenger, students can click the "Message" button. Engaging with Paito Gorus can be as simple as initiating the conversation with greetings like "hi," "hello" or "hey there," as depicted in Figure 1 Paito Gorus initiates with a greeting.

Figure 2 illustrates that students have the option to choose a specific subtopic within integration for their learning. The featured subtopics in this Paito Gorus include integration rules, integration by substitution, integration by parts, definite integrals and substitution in



Source(s): Authors' own work

Figure 1. Introduction of conversational agent

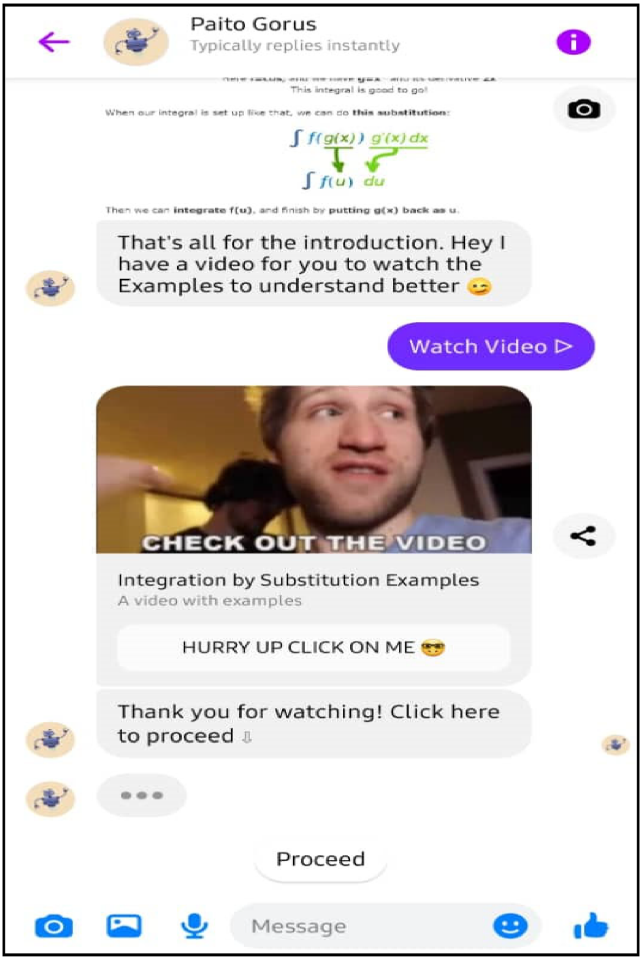
Source(s): Authors' own work

Figure 2. Overview of subtopics

definite integrals. Each subtopic commences with a concise introduction, followed by examples and exercises, as depicted in Figure 2.

After introducing the subtopic, students have the option to view a video showcasing multiple examples (Figure 3). The video is effectively delivered, featuring an instructor who provides guidance and explanations using numerous examples. The solutions are explained through straightforward and step-by-step instructions.

After mastering a particular subtopic, students engage in solving integration problems associated with that subtopic. This approach proves effective in solidifying their comprehension of the lesson. In Figure 4, exercises are presented for students to practice at the conclusion of each subtopic. The exercises commence with straightforward questions and progressively advance to more complex ones in sequence. Students have the flexibility to opt for alternative subtopics if they prefer not to attempt the exercises. Additionally, motivational messages are incorporated to inspire students to tackle more challenging problems.



Source(s): Authors' own work

Figure 3. Examples in conversational agent

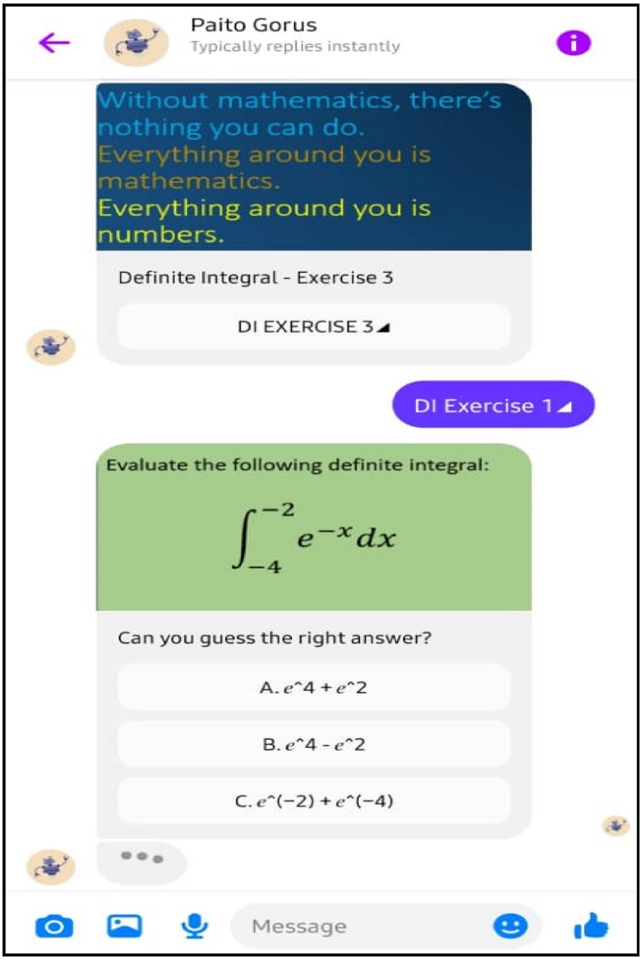
Figure 5 illustrates the results of students responding to questions, with Paito Gorus providing affective feedback after each answer. During the activity, students receive hints in case of incorrect responses, and even if they answer correctly, they can choose to review the solutions step by step.

Results

This section presents the two attitude dimensions results. The data gathered from participants underwent analysis through a paired sample *t*-test to compare the mean differences between the pre-test within the control and experimental groups.

(1) Dimension 1: Importance of mathematics

(2) Dimension 2: Anxiety toward mathematics

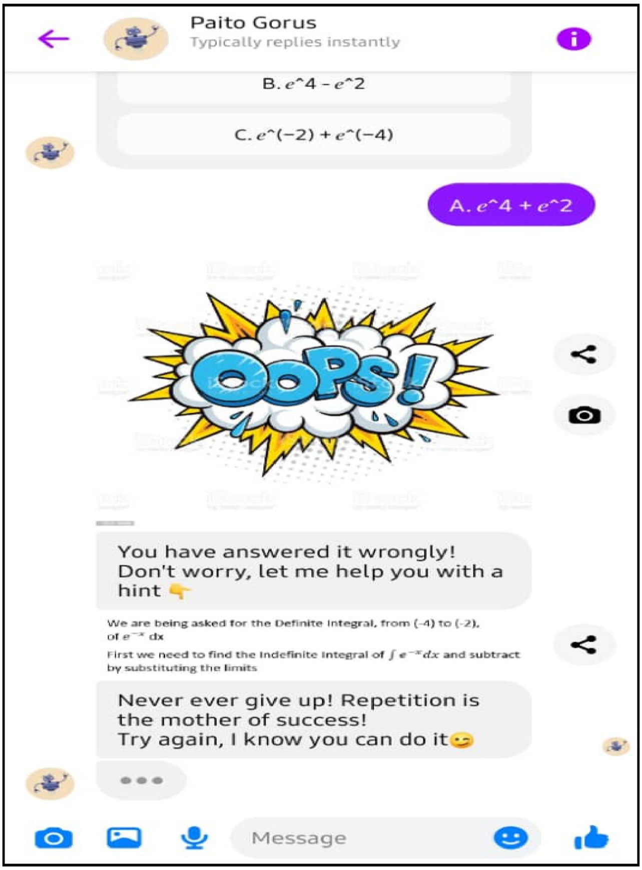


Source(s): Authors' own work

Figure 4. Exercises in conversational agent

Table 2 presents the results of comparing the importance dimensions' pre- and post-test within the control and experimental groups. For the control group, the mean score for the pre-test was 3.90, with a standard deviation (SD) of 0.73, whereas the post-test had a mean score of 4.04, with a SD of 0.69. For the experimental group, the mean score for the pre-test was 4.08, with a SD of 0.64, while the post-test had a mean score of 4.01, with a SD of 0.64. There was no significant difference found in the importance dimension between the pre- and post-test in both the control and experimental groups, $p > 0.05$.

Table 3 shows the results comparing pre- and post-tests of the importance dimension between control and experimental groups. The importance dimension was not significantly different between the control ($M = 3.90$, $SD = 0.73$) and experimental groups ($M = 4.08$, $SD = 0.64$) in the pre-test, $p > 0.05$. The importance dimension was not significantly different between the control ($M = 4.04$, $SD = 0.69$) and experimental groups ($M = 4.01$, $SD = 0.64$), in the post-test as well, $p > 0.05$. There was no significant difference in both the pre- and post-test for the importance of mathematics.



Source(s): Authors' own work

Figure 5. Students answering questions in conversational agent

Table 2. Paired sample *t*-test of importance dimension

Group	*N*	Test	Mean	SD	*t*-value	*p*-value
Control	85	Pre	3.90	0.73	−1.20	0.23
		Post	4.04	0.69		
Experimental	115	Pre	4.08	0.64	0.88	0.21
		Post	4.01	0.64		

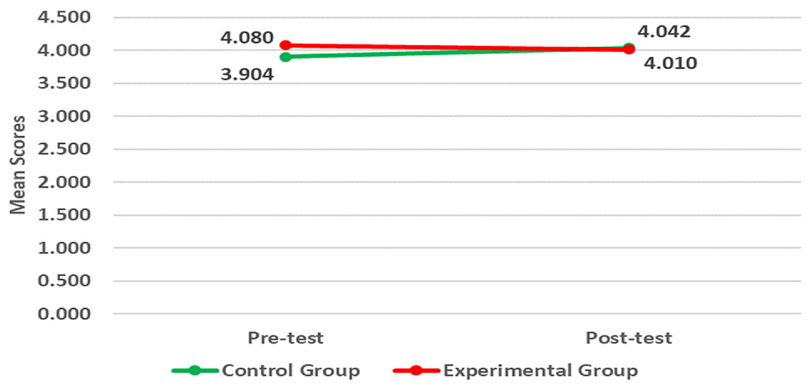
Source(s): Authors' own work

Figures 6 and 7 provide a visual comparison of the mean scores for better comprehension of trends observed in the data. Figure 6 illustrates a comparison of importance dimension scores between the control and experimental groups both before and after the intervention. In the pre-test, the experimental group exhibited a higher score (M = 4.080), whereas the control group had a lower score (M = 3.904). Conversely, in the post-test, the experimental group displayed lower mean scores (M = 4.010), whereas the control group showed higher mean scores

Table 3. Independent sample *t*-test of importance dimension

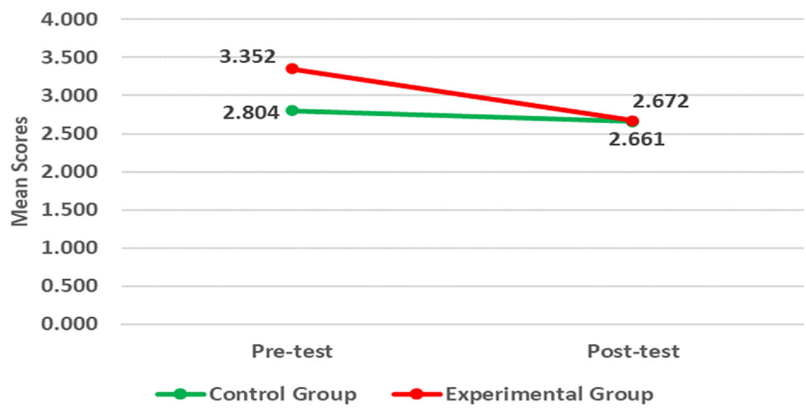
Group	*N*	Test	Mean	SD	*t*-value	*p*-value
Pre	85	Control	3.90	0.73	−1.83	0.31
		Experimental	4.08	0.64		
Post	115	Control	4.04	0.69	0.34	0.06
		Experimental	4.01	0.64		

Source(s): Authors' own work



Source(s): Authors' own work

Figure 6. Mean scores of importance dimension in pre- and post-test



Source(s): Authors' own work

Figure 7. Mean scores of anxiety dimension in pre- and post-test

(M = 4.042). This suggests that, throughout the intervention, the control group students' perceived importance of mathematics increased, while the experimental group students' importance of mathematics decreased from the pre- to post-test.

Table 4 shows the results comparing the anxiety dimensions' pre- and post-test within both groups. The mean score of the pre-test was 2.80 with a SD of 0.88, while the mean score of the

Table 4. Paired sample *t*-test of anxiety dimension

Group	*N*	Test	Mean	SD	*t*-value	*p*-value
Control	85	Pre	2.80	0.88	1.14	0.26
		Post	2.66	0.76		
Experimental	115	Pre	3.35	0.94	5.75	0.05
		Post	2.67	0.70		

Source(s): Authors' own work

post-test was 2.66 with a SD of 0.76 for the control group. The mean score of the pre-test was 3.35 with a SD of 0.94, while the mean score of the post-test was 2.67 with a SD of 0.70 for the experimental group. There was no significant difference found in the anxiety dimension between the pre- and post-test in the control group, $p > 0.05$, whereas there was a significant difference in the experimental group, $p \leq 0.05$.

Table 5 presents an independent samples *t*-test to compare pre-test scores between the experimental ($M = 3.35$, SD $= 0.94$) and control groups ($M = 2.80$, SD $= 0.88$). The results indicated a significant difference, $p < 0.05$, suggesting initial disparities in attitudes toward mathematics between groups. An ANCOVA was conducted in Table 6 with pre-test scores as a covariate to adjust for baseline differences. After adjustment, the post-test scores showed a significant reduction in anxiety for the experimental group compared to the control group, $F = 39.46$, $p < 0.05$.

Figure 7 illustrates the anxiety dimension outcomes for both the control and experimental groups before and after the test. Anxiety levels decreased for the control group students from pre-test ($M = 2.804$) to post-test ($M = 2.661$) and similarly for the experimental group students from pre-test ($M = 3.352$) to post-test ($M = 2.672$). Notably, the experimental group experienced a more substantial reduction in anxiety compared to the control group, as depicted in Figure 7.

Discussion

The findings indicate that the importance of mathematics did not change significantly in both the control and experimental groups before and after the study. A potential explanation for students viewing mathematics as less important might be a perceived lack of real-world relevance (Gunduz and Saracbasi, 2022). For students not intending to pursue STEM careers,

Table 5. Independent sample *t*-test of anxiety dimension

Group	*N*	Test	Mean	SD	*t*-value	*p*-value
Pre	85	Control	2.80	0.88	5.93	0.01
		Experimental	3.35	0.94		

Source(s): Authors' own work

Table 6. ANCOVA of anxiety dimension

Source	Type III sum of squares	Mean square	*F*	*Sig*	Partial Eta squared ($\eta_p$$^{2)}$
Group	22.02	22.02	39.46	0.00	0.17

Source(s): Authors' own work

the lack of effective communication regarding the relevance of mathematical concepts to real-world situations can lead to a perception of mathematics as abstract and unrelated to their daily experiences (Chen *et al.*, 2018). Limited exposure to diverse career possibilities in information technology, coupled with curriculum designs that may not emphasize the practical application of mathematics, influences students' perceptions of its importance. Moreover, some IT courses prioritize programming languages and other practical aspects, leading students to view math as less relevant.

The results suggest that anxiety toward mathematics decreased in both the control and experimental groups during the post-test. However, it was only in the experimental group where a significant reduction in anxiety toward mathematics was observed. The inclusion of a CA in the intervention might have contributed to easing the performance pressure felt by the students in the experimental group (Yin *et al.*, 2021). The CA offers a supportive and nonjudgmental learning environment that enables students to explore mathematical concepts freely, alleviating performance pressure and anxiety associated with evaluation (Patel, 2022). This shift allows students to concentrate on learning and problem-solving rather than on meeting external expectations. Furthermore, researchers have discussed that CA might have promoted increased engagement among students in the experimental group in comparison to traditional teaching methods (Rooein, 2019; Chen *et al.*, 2020). The experimental group students may have experienced reduced anxiety toward mathematics compared to the control group due to receiving affective feedback from the CA, such as encouragement and congratulations, which likely provided greater reassurance.

The incorporation of CA not only aided students in grasping the connection between theory and practice but also offered immediate solutions to the challenges they faced. This could have reduced their anxiety in both learning and practical application (Tsai and Hwang, 2021). As suggested by Zhu *et al*. (2022), the progressive escalation in question difficulty within the CA could have contributed to enhancing students' confidence in mathematics, which may explain the significant reduction in anxiety in the experimental group. The integration of social dialog in the CA may have contributed to reducing students' anxiety toward mathematics, fostering a supportive and friendly learning atmosphere (Qin *et al.*, 2020). Besides that, the CA provides interactive and dynamic learning experiences, motivating students to actively engage in mathematical tasks and problem-solving, thereby assisting in reducing students' anxiety and increasing their overall confidence in their mathematical abilities. This comprehensive approach not only makes learning more enjoyable but also ensures that students feel more competent and less apprehensive about their mathematical abilities, leading to a more positive overall attitude toward the subject.

Conclusion

To conclude, the objective of this study was to examine the effectiveness of integrating CA on students' attitude toward mathematics, which was achieved. While no significant improvement was observed in the importance of the mathematics dimension. However, the experimental group that experienced both traditional teaching and the CA exhibited significantly reduced anxiety toward mathematics compared to the control group. To personalize learning and improve outcomes, educational institutions should explore implementing a CA in their teaching practices. Further research is needed to understand how a CA can be best utilized across different subjects and grade levels as well as its long-term effects on students' attitudes.

While this study provides valuable insights, it is important to acknowledge its limitations. While the data comes from a single university cohort under the same instructor, potential discrepancies might exist due to the lack of diverse learning environments that could influence students' attitudes. This study's narrow focus on a single topic limits the generalizability of the results to similar subjects and topics only. The duration of the intervention in the study has been relatively short, which limits the assessment of long-term effects. Additionally, the students' attitude toward mathematics is limited to only two dimensions of attitude. Another limitation of the study is that it relied on pre-existing groups formed during student registration for lecture and tutorial sessions due to administrative constraints. Reshuffling these groups would have required significant changes to the timetable, classroom allocations and lecturer or tutor assignments, making it impractical. Furthermore, the lack of prior research on the impact of CAs in mathematics education restricts the study's generalizability. Time constraints prevented this study from conducting interviews to gather students' opinions on mathematics following the intervention and their perceptions of the system. This limitation restricts the depth of understanding of students' experiences and perspectives. Additionally, the cost is a significant factor limiting the integration of CA across different platforms.

Despite the acknowledged limitations, some recommendations can be applied to assist future researchers working on similar topics. To enhance the comprehensiveness of data collection and improve results, it is advisable to incorporate diverse universities where students are instructed by various lecturers in different environments. Future researchers may also enhance the applicability of their findings across various educational settings by including secondary schools. This diversity can significantly influence students' attitudes and offer valuable insights into the range of data that can be obtained. Furthermore, the inclusion of various topics can be explored to determine whether there is any notable impact on students' attitudes across different subjects presented to them. The duration of the intervention needs to be extended to observe the effects of the intervention over a longer period. Conducting longer-term follow-ups would be beneficial to assess whether the improvements in mathematics anxiety are maintained over time or if they diminish over an extended period. A more comprehensive understanding of students' attitudes toward mathematics requires considering additional dimensions. Additionally, interviews can be conducted to gather qualitative data that provides insights into students' opinions, attitudes and subjective feedback regarding the agent's usability, effectiveness and overall satisfaction. This will also help in understanding students' perceptions, which can guide the enhancement of the agent. Lastly, future research should consider budgeting for the integration of a CA into WhatsApp, a widely used social messaging platform. This integration would facilitate easy access for students, removing any potential barriers.

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