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DEVELOPMENT AND VALIDATION OF AN INSTRUMENT FOR ASSESSING STUDENTS' PERCEIVED EFFECTIVENESS OF AI-ENHANCED ADVANCED MATHEMATICS COURSES

Sheng Jie¹, Nor Hasnida Che Md Ghazali^{2*}

¹Faculty of Human Development, Universiti Pendidikan Sultan Idris, Malaysia

 1253141913@qq.com

 <https://orcid.org/0009-0000-1686-0425>

²Faculty of Human Development, Universiti Pendidikan Sultan Idris, Malaysia

 hasnida@fpm.upsi.edu.my

 <https://orcid.org/0000-0001-7891-4943>

*Corresponding Author

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Abstract:

This study developed a measurement tool to assess students' perceived effectiveness of an AI-enhanced advanced mathematics course and verified its validity and reliability. As artificial intelligence (AI) technologies become more prevalent in higher education, AI-supported learning environments have emerged as a promising approach to enhancing educational quality and enriching students' learning experiences. Nevertheless, at present, existing research has yet to provide adequately developed quantitative measurement tools capable of assessing students' perceptions of the effectiveness of AI-enhanced advanced mathematics courses and their learning outcomes. Therefore, based on prior research and educational theory, this study developed a measurement tool to evaluate students' perceived learning outcomes in an AI-enhanced advanced mathematics learning environment. This instrument comprises four dimensions: 'improvement in mathematical understanding', 'development of mathematical thinking skills', 'changes in motivation to learn', and 'satisfaction and willingness to recommend'. A convenience sampling method was used for the preliminary study, which involved 98 undergraduate students enrolled on an advanced mathematics course utilising AI. Five experts in educational technology and mathematics education were invited to assess the instrument's content validity through the Content Validity Index (CVI). The results showed that the average Content Validity Index for the entire scale (S-CVI/Ave) was 0.85, confirming sufficient content validity. Internal consistency reliability was then checked using Cronbach's α coefficients. The reliability analysis revealed that all four dimensions showed acceptable to strong consistency, with α values ranging from 0.754 to 0.866. The results offer initial empirical support

for the reliability and validity of the proposed tool for assessing students' perceived effectiveness of the AI-enhanced advanced mathematics course. This instrument can assist educators and higher education institutions in evaluating students' learning experiences, identifying areas for improvement, and optimising AI-enhanced mathematics teaching practices. In future research, it will be necessary to conduct exploratory and confirmatory factor analyses using a larger and more diverse sample to further validate the measurement instrument.

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Keyword:

AI-enhanced Advanced Mathematics, Content Validity, Instrument Development, Pilot Study, Reliability, Students' Perceived Effectiveness



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Introduction

Research Background

Although AI technologies are now being used more and more widely in higher education, research has not yet been carried out systematically to study students' perceptions of the effectiveness of AI-enhanced advanced mathematics courses. Most of the previous research has focused on AI teaching models, technology platforms or teachers' perceptions, and has not quantitatively assessed students' perceived learning experiences and outcomes in AI-enhanced instructional environments (Liu, 2023). Owan et al. (2023) indicated that the present research has focused primarily on tool-based applications of AI in educational assessment and have failed to systematically investigate students' perceptions of the efficacy of AI-enhanced learning. Othman et al. (2024) also conducted a bibliometric analysis to find that international research on artificial intelligence in education is heavily concentrated on intelligent algorithms as well as automated assessments, but there are relatively few studies exploring how students perceive the efficacy of AI-aided classes.

Therefore, a reliable and valid scientific and systematic instrument has been developed to assess students' perceived effectiveness of AI-enhanced advanced mathematics courses (Zhao, 2025; Owan et al., 2023). Based on the review of domestic and foreign research on artificial intelligence in education and educational assessment (Owan et al., 2023; Othman et al., 2024; Zhao, 2025), this paper develops a tool to evaluate students' sense of the effectiveness of AI-

enhanced Advanced Mathematics courses, which includes the four main dimensions mentioned below: Mathematical Understanding – to examine changes in students' conceptual comprehension, academic results and problem-solving abilities (Liu, Zhang, & Wang, 2026); Mathematical Thinking – to determine progress in logical reasoning, abstract thinking and analytical skills (Eti, Mosia, & Egara, 2026); Learning Interest – to observe how much students are interested in, taking the initiative to learn and motivated by Advanced Mathematics; and Satisfaction and Willingness to Recommend – to reflect students' general feelings about the course and how likely they are to recommend it to others.

Expert content validity evaluation and reliability analysis (CVI and Cronbach's α) is going to be performed to make sure the validity and reliability of this instrument across the four dimensions, providing a scientific and quantitative basis for evaluating students' perception of the effectiveness of AI-enhanced advanced mathematics courses. The instrument will be used in subsequent large-scale empirical studies to advance research on AI-enhanced mathematics education in higher education.

The developed instrument has important practical implications for higher education. By measuring students' perceived effectiveness of AI-enhanced Advanced Mathematics courses, universities can obtain empirical evidence regarding students' learning experiences, identify areas requiring improvement, and optimize AI-supported instructional strategies. Furthermore, the instrument may be used as a guide for educators who intend to evaluate and enhance AI-integrated mathematics teaching practices.

Research Problem

As artificial intelligence (AI) technologies become more prevalent in higher education, AI-assisted teaching has gradually been applied to drive the digital transformation of education and improve teaching quality. Advanced Mathematics is a foundational course for the departments of Science and Engineering, and thus needs to cultivate students' logic, abstraction and creativity. However, traditional advanced mathematics teaching often has problems such as being too abstract, lacking students' interest, and having limited interaction in the classroom; therefore, new technologies need to be introduced to improve students' learning experience. The introduction of AI technology will bring new possibilities for personalised education and intelligent feedback by means of intelligent learning systems, automatic tests, visual demonstrations and smart tutors, and thus improve the students' sense of achievement in learning (Liu, Zhang, & Wang, 2026).

Although the "AI + Education" model has been widely used in higher education, systematic instruments to measure students' perceived benefits of AI-empowered advanced mathematics courses are still lacking. Most studies to date have focused on technological platforms, teaching models or students' perceptions, but quantitative evaluation tools specifically designed to measure the degree of students' perception in all aspects of learning are still lacking. In addition,

although research has demonstrated that AI-enhanced learning environments are able to boost students' interest in learning and improve their grades, there is a lack of systematic and quantitative data on how students' mathematical understanding, development of mathematical thinking, learning interest and course satisfaction have changed.

Therefore, a scientific and systematic tool with good reliability and validity for measuring students' perceptions of the effectiveness of AI-empowered Advanced Mathematics courses needs to be developed (DeVellis & Thorpe, 2021). Such a tool can help us collect data on how students experience learning and what they have learned, providing support for continuous improvement of teaching. It can help universities conduct scientific research on the influence of AI-assisted teaching methods and promote deep integration and long-term development of "AI + education" in higher education. Drawing on relevant domestic and foreign research on educational technology and mathematics education, this study proposes the four main measurement indicators: mathematical understanding, mathematical thinking, learning interest, and satisfaction and willingness to recommend.

Research Questions

This paper will develop and validate a scale to assess students' perceptions of the impact of AI-enhanced Advanced Mathematics courses. The research aims to find:

According to expert judgment of item relevance, clarity and coverage, determine the CVI of the instrument.

Using Cronbach's alpha coefficient to evaluate the internal consistency reliability of both individual dimensions and entire scale.

Literature Review

As artificial intelligence (AI) technologies become more prevalent in higher education, AI-enabled teaching has gradually emerged as a new form of educational innovation to drive the digital transformation of education and improve teaching as well as learning. Four types of AI applications in higher education that have been covered by systematic reviews are: intelligent tutoring, personalised support, adaptive feedback and learning resource management. The above applications will change the mode of teaching and learn more student-centered ways. For example, research has shown that AI-driven adaptive learning platforms and personalised learning environments can dynamically adjust content and feedback according to students' learning behaviour, thus improving learning efficiency and interest (Peng & Li, 2025; Merino-Campos, 2025). AI-integrated learning analytics are able to be used to assess and predict students' learning progress in real time, provide support as well as decision-making tools for teachers, and thus promote student-centered teaching (Merino-Campos, 2025).

AI Technology in Mathematics Education Also Has Good Potential. According to the above data, AI tools have improved the results of mathematics classes. For example, a recent meta-analysis has revealed that generative AI has a moderate positive influence on students' performance and learning results in mathematics, thus offering empirical support for AI-enhanced mathematics instruction (Liu et al., 2026).

Based on the above research, many people believe that AI-assisted personalised learning, automatic feedback mechanisms, and intelligent tutoring systems can help students better understand abstract mathematical ideas and use them in real life. Intelligent Tutoring Systems are now mature applications of artificial intelligence that provide students with individual exercises and instant feedback to help them learn the basic concepts of mathematics better (Son, 2024).

Based on the above research, an AI-driven learning environment can provide timely feedback and visual explanations for students at various stages of learning to promote their development of logical thinking and systematic thinking. Adaptive and personalised learning systems are able to assist students learn at their own speed and explore different levels of difficulty in mathematics to develop their thinking skills (Ingkavara et al., 2023).

Learning interest can be stimulated by AI teaching and research to provide individualised feedback, personalised recommendation, interactive exercises, etc. There will be more enthusiasm and more people participating in the class as a result. Therefore, AI will be used to inspire students in the Advanced Mathematics course (Li, 2025).

Although existing studies have mainly focused on technology acceptance and instructional effectiveness, systematic reviews have shown that students' satisfaction and willingness to recommend are closely related to the perceived usefulness, feedback quality and usability of AI-assisted learning tools, and all of these factors also influence their willingness to recommend the course. Therefore, satisfaction and recommendation intention can be used to measure how effective students feel AI-enhanced learning environments are and need to be studied more formally using quantitative methods (Crompton & Burke, 2023).

Although previous research has shown the significant potential of AI in teaching advanced mathematics, little systematic quantitative research focuses on how students perceive the four core aspects of this learning: mathematical understanding, mathematical thinking, interest in learning, and satisfaction/willingness to recommend. Research on educational technology at present often uses different indicators and measurement methods, and there is a lack of a specific, validated tool for evaluating students' perception of the effectiveness of AI-enhanced advanced mathematics courses (Bond et al., 2024). Therefore, a scientific, systematic, reliable and valid measurement tool needs to be developed to evaluate students' sense of learning and their learning experience in AI-supported learning environments accurately (DeVellis & Thorpe, 2021). Therefore, this paper aims to develop and validate a tool for measuring students'

perception of the effectiveness of AI-enhanced Advanced Mathematics courses. The four dimensions of the instrument are mathematical understanding, mathematical thinking, learning interest, and satisfaction and willingness to recommend; it hopes to offer a reliable and valid tool for future empirical research and promote continuous improvement of AI-supported mathematics education in higher education.

Conceptual Framework

The three theories supporting this study are educational informatisation theory, constructivism and STEM education theory, etc., which collectively provide the theoretical foundation for examining students' perceptions of the effectiveness of AI-enhanced advanced mathematics courses. Educational informatisation theory promotes innovation and reform in teaching and learning through the application of information and communication technologies (ICT). For instance, in the process of reforming university teaching, modern educational technology and ICT have been used to increase the degree of interaction in classes, optimise the utilisation of resources, and provide personalised learning pathways (Ji, Dai, & Wang, 2024). According to constructivist learning theory, learners actively build their own knowledge systems for deeper understanding by means of autonomy, contextualized experiences and social interaction. This theoretical system has been widely used to foster good learning conditions in mathematics and integrated learning environments (Merino-Campos, 2025). The integration of science, technology, engineering, and mathematics is encouraged by STEM education, which also fosters students' capacity for creative problem-solving. Research shows that through interdisciplinary task design; STEM practices can promote higher-order thinking and applied abilities. Together, the three above theories provide the foundation and analytical system for this paper.

Based on the above theory, this study investigates students' perceptions of the effectiveness of AI-enhanced advanced mathematics courses in four aspects. First, mathematical understanding assesses how students have learned new mathematical knowledge and skills in the era of AI assistance for learning. Research in educational technology has shown that AI-assisted learning systems can improve the performance of learners in learning abstract concepts and problem-solving (Holmes, Bialik & Fadel, 2019). Second, mathematical thinking refers to the students' own feelings of the growth of logical reasoning, abstract thinking and analytical abilities, and AI can assist them in achieving this. Previous research has found that adaptive intelligent tutoring systems and visualised feedback tools can promote the development of logical thinking and mathematical thinking in students (Becker & Park, 2011). Third, learning interest refers to a student's sense of motivation, participation, and other factors in learning with artificial intelligence. Based on the above research, intelligent interactive learning environments have significantly increased both interest and participation. Finally, satisfaction and willingness to recommend reflect the students' overall satisfaction with the AI-assisted learning experience and their willingness to recommend the course to other students; they indicate the degree of acceptance and recognition of AI-enhanced instruction. Based on the above data, most students are happy about the use of AI for learning and want to keep using it.

In short, the conceptual framework aims to explain the connections among mathematical understanding, mathematical thinking, learning interest, and satisfaction and willingness to recommend as indicators of students' perceived effectiveness in AI-enhanced advanced mathematics courses. Through the development and validation of this framework, this study aims to build a scientific instrument for evaluating students' perception of the effectiveness of AI-enhanced Advanced Mathematics courses. The instrument is to be used as a reliable and valid measurement tool for future empirical research to support the ongoing development of AI-assisted mathematics education at the university level (DeVellis & Thorpe, 2021).

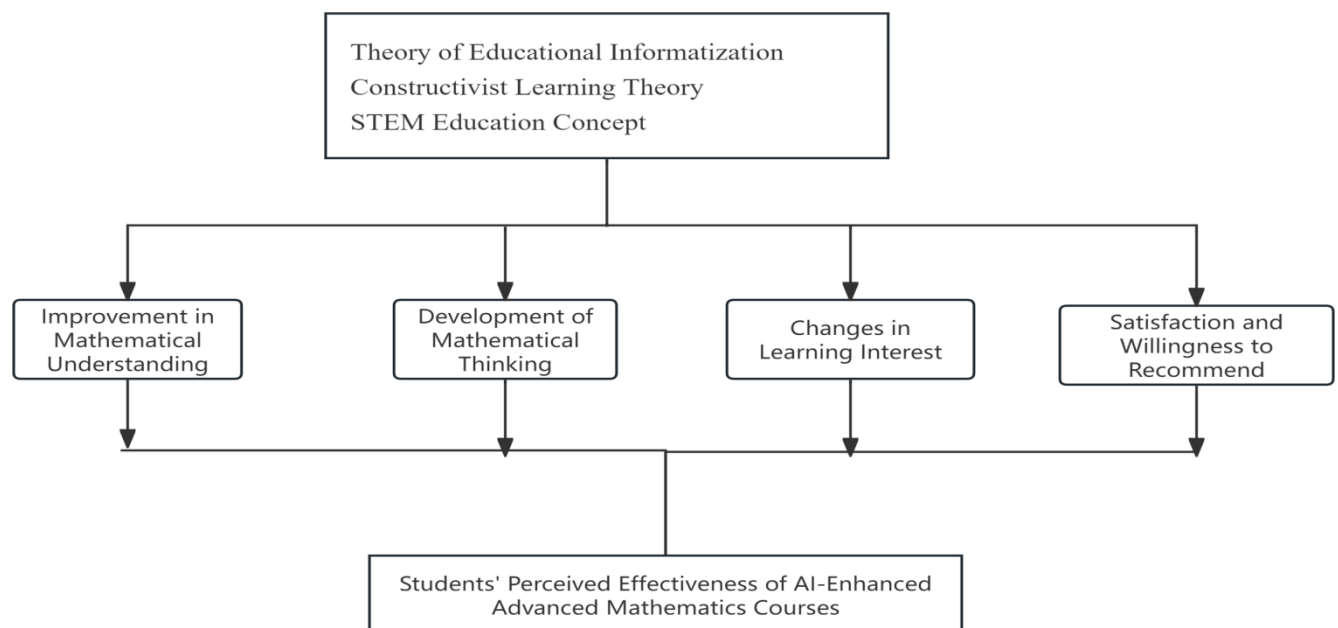


Figure 1: Conceptual Framework For Assessing Students' Perceived Effectiveness Of AI-Enhanced Advanced Mathematics Courses

Methodology

Research Design

A quantitative research method was used to develop and validate a tool for evaluating how effective students feel their AI-enhanced advanced mathematics courses are. Questionnaires were distributed to obtain data. Systematically collect data in a quantitative survey and make sure the validity and reliability of the instrument (Creswell & Creswell, 2017).

Before the study, a content validity test of the questionnaire was conducted to ensure the items covered all aspects of the intended variables. According to the above, expert review and written evaluation forms were performed to determine content validity according to the established procedures for instrument development and validation (Haynes, Richard, & Kubany, 1995).

The two groups of expert evaluation were professional and content experts, as well as field and teaching-practice experts, to ensure that both the instrument's theoretical relevance and practical application were sound (Polit & Beck, 2006).

Purposive expert sampling was used to select evaluators who had related expertise and professional experience in mathematics education, educational technology and higher education teaching (Etikan, Musa & Alkassim, 2016). Therefore, a selection method suitable for experts was used to determine whether questionnaire items covered the expected dimensions of students' perceived effectiveness in AI-assisted advanced mathematics courses. With the consent of five experts who participated in the content validity assessment, two professional experts from the field of mathematics education and educational technology, and three field experts with extensive university teaching experience, were included. All of the experts have worked in education for more than five years.

The experts were given the following materials: an invitation letter, a research brief, questionnaire items and content validity evaluation forms. All items of the questionnaire were evaluated according to the extent of their utility, understandability and all-encompassing nature on a five-point Likert scale. Table 1 lists backgrounds of appointed experts.

Table 1 : Selection Of Experts For Content Validity Based On Area Of Expertise

Content Validity Process

Expert	Position	Area of Expertise	Institution
A	Lecturer	English Language Teacher	Shandong Huayu University of Technology
B	Lecturer	Advanced Mathematics Teacher	Shandong Huayu University of Technology
C	Associate Professor	Educational Assessment	Qufu Normal University
D	Lecturer	AI Teacher	Shandong Huayu University of Technology
E	Professor	Advanced Mathematics Teacher	Shandong Huayu University of Technology

The content validity analysis in this study serves as the validation for ensuring that items in the questionnaire are related to the intended constructs, clear and representative. To determine whether the items of the questionnaire were deemed reasonable, a small group of specialists has reviewed them and a CVI has been computered based on the specialists' opinions. The two

components of the CVI are the item-level content validity index (I-CVI) and the S-CVI, and they indicate the content validity at the item and overall instrument levels, respectively (Yusoff, 2019). Recently, some research has shown that CVI has been extensively used in the development of questionnaires for educational and social science research, and it offers empirical support for decisions on whether to keep, revise or delete items (Romero Jeldres, Díaz Costa & Nadim, 2023).

Experts with backgrounds in mathematics education, educational technology and higher education teaching independently assessed the questionnaire items in this study. According to the above ratings, the researchers determined the I-CVI and S-CVI values to evaluate the content validity of the instrument. Based on the results, it was determined that questionnaire items adequately covered dimensions of students' perceived effectiveness of AI-enhanced advanced mathematics courses and thus provided support for the content validity of the instrument.

Population And Sample

The subjects of this study were undergraduate students taking AI-enhanced advanced mathematics courses, and convenience sampling was used to select some of these students who were convenient to reach. Therefore, a representative sample is often taken in a pilot study to help collect data efficiently and to provide preliminary information on the accuracy and reliability of new instruments (Etikan et al., 2016).

Pilot Study

A small-scale experiment was conducted prior to this main study to make sure that the questionnaire is feasible and reasonably reliable at the start. The purpose of pilot testing in the development of a test is to identify problems such as vague items or flaws in administration methods at an early stage and thus to improve the overall quality of the test before its large-scale use (DeVellis & Thorpe, 2021).

Total 98 undergraduate students from the university took part in the pilot study. Administer the questionnaires and collect them according to the above plan. The pilot data were used to investigate the preliminary reliability and practical feasibility of the instrument, as well as to determine whether the questionnaire items were suitable for assessing students' perceived effectiveness of AI-enhanced Advanced Mathematics courses.

Research Instrument

A set of standardised question sheets served as the first method of data collection. Four dimensions of the questionnaire were designed to evaluate students' perceptions of the effectiveness of AI-enhanced Advanced Mathematics courses: Mathematical Understanding, the degree to which students feel their conceptual understanding and knowledge application in Advanced Mathematics have been enhanced, and problem-solving skills. Mathematical

Thinking - Refers to the extent to which students can use logical reasoning, analysis, abstraction and mathematical modelling. Learning Interest - The extent of a student's interest, motivation, engagement and active participation in learning advanced mathematics. Satisfaction and Willingness to Recommend - Indicators of how satisfied students are with their all-around experience of learning using AI, and how likely they are to recommend this course to others.

All the items were scored from 1 to 5. Based on recommendations from educational and psychometric research, a five-point scale has been adopted to measure students' attitudes, perceptions and self-assessments, as it has proven to be valid and reliable, is simple for students to understand and complete (Joshi, Kale, Chandel & Pal, 2015; Revilla, Saris & Krosnick, 2014). The scale items are as follows:

1	—	Strongly	Disagree
2	—		Disagree
3	—		Neutral
4	—		Agree
5	Strongly Agree		

The questionnaire items were modified according to Akpur et al. (2016), Song (2024), and other recent studies on AI-assisted education to ensure full coverage of the dimensions under the students' perceived effectiveness in AI-enhanced advanced mathematics courses. Each construct's item count is displayed in Table 2.

Table 2 : Distribution Of Items Measured Based On The Specified Constructs

Construct	Number of Items
Mathematical Understanding	5
Mathematical Thinking	5
Learning Interest	5
Satisfaction and Willingness to Recommend	5

Results

Content Validity Analysis

CVI used for questionnaire assessment. The results show that the instrument reached a S-CVI of 0.85 and met the common threshold of 0.80 for acceptable content validity (Rahmat, Saidi, & Mohd Nasir, 2024). Therefore, the instrument has good content validity and comprehensively covers the intended constructs in terms of item relevance, clarity and representativeness.

Content validity analysis can show whether the contents of the questionnaire are reasonable and provide a system for selecting or modifying items to be used in the questionnaire. Previous studies on educational measurement have shown that the CVI method is often used in questionnaire construction to determine how much experts agree that the items are in line with the variables to be observed (Wang & Sahid, 2024). Expert evaluation and CVI analysis have also been widely employed in practice to enhance the scientific credibility of new instruments (Ahmad & Idris, 2025).

Therefore, based on the above, it can be concluded that the instrument has good content validity, and the items are in line with the four dimensions of students' perceived effectiveness of AI-enhanced advanced mathematics courses: mathematical understanding, mathematical thinking, learning interest, and satisfaction and willingness to recommend. The above results show that the instrument is suitable for the following reliability tests and future large-scale validation studies. The CVI values of the different constructs are shown in Table 3.

Table 3 : CVI Analysis Based On Expert Evaluation

Construct	Number of Items	S-CVI
Mathematical Understanding	5	0.84
Mathematical Thinking	5	0.84
Learning Interest	5	0.88
Satisfaction and Willingness to Recommend	5	0.84
Total	20	0.85

Five experts were invited to assess the relevance and clarity of each item in the questionnaire and provided a 5-point score. Ratings of 4 and 5 were regarded as items with good relevance. The I-CVI was calculated for each item, and then the S-CVI/Ave for each construct and for the whole instrument were computed. The results show that the S-CVI/Ave is approximately 0.85 and thus exceeds the standard threshold of 0.80. Based on the above analysis, it is found that the instrument meets the requirements for content validity, and the questionnaire items are generally consistent with the theoretical models of the underlying variables; this aligns with the findings reported by Wang and Sahid (2024) on educational measurement and instrument development.

Among these, two items obtained relatively low I-CVI values (0.60). These items belonged to the constructs of “Mathematical Understanding” and “Mathematical Thinking,” respectively. Although their content validity scores were lower than those of the other items, the researchers considered them theoretically important because they reflected key learning outcomes in AI-enhanced advanced mathematics courses. Conceptual understanding and mathematical thinking are widely recognized as core objectives in mathematics education and important indicators of student development. Therefore, these items were retained at the content validation stage.

Given their theoretical significance, the researchers decided to retain the two items and include them in the subsequent pilot testing phase for further evaluation. During the pilot study, their measurement performance was assessed through item analysis and reliability analysis. Based on the combined results of these analyses, decisions regarding the retention or deletion of the items were made.

Although the I-CVI values of these individual items were relatively low, the overall S-CVI/Ave of the instrument remained above the recommended threshold of 0.80. Therefore, the instrument was considered to possess satisfactory content validity overall. In summary, the results indicate that the instrument was appropriate for proceeding to the pilot testing stage, where the quality of the items and the structure of the scale could be further examined and refined through empirical analysis.

Instrument Reliability

Table 4 demonstrates the reliability analysis results of the Product evaluation constructs. The Cronbach's Alpha coefficient for Improvement in Mathematical Understanding was 0.754, indicating an acceptable level of internal consistency reliability. The Corrected Item–Total Correlation (CITC) values ranged from 0.336 to 0.679. Among the items, D1-3 obtained a CITC value of 0.336, which was below the recommended threshold of 0.40. Furthermore, the Cronbach's Alpha coefficient would increase from 0.754 to 0.788 if the item were deleted. Therefore, D1-3 was removed from the instrument.

For the Development of Mathematical Thinking construct, the Cronbach's Alpha coefficient was 0.841, indicating good reliability. The CITC values ranged from 0.529 to 0.700, all exceeding the recommended minimum value of 0.40. Additionally, the deletion of any item would result in a lower Cronbach's Alpha coefficient. Therefore, all items in this construct were retained.

The Change in Learning Interest construct achieved a Cronbach's Alpha coefficient of 0.866, indicating high internal consistency. The CITC values ranged from 0.631 to 0.754, all of which exceeded the recommended threshold. Since the deletion of any item would reduce the overall reliability coefficient, all items were retained.

Similarly, the Satisfaction and Willingness to Recommend construct obtained a Cronbach's Alpha coefficient of 0.795, suggesting satisfactory reliability. The CITC values ranged from 0.380 to 0.744. Item D4-3 recorded a CITC value of 0.380, which was below the recommended threshold of 0.40. Moreover, deleting this item would increase the Cronbach's Alpha coefficient from 0.795 to 0.815. Therefore, D4-3 was removed from the instrument.

Overall, the findings of the reliability analysis showed that the product evaluation constructs had acceptable to good internal consistency dependability. Two items (D1-3 and D4-3) were eliminated based on the CITC values and the Cronbach's Alpha if Item Deleted statistics. The remaining questions were kept for the final version of the survey.

Table 4 : Cronbach's Alpha Values If Item Deleted And Overall Cronbach's Alpha For The Constructs

Product Evaluation Constructs	Item	Corrected Item–Total Correlation (CITC)	Cronbach's Alpha if item deleted	Overall Cronbach's Alpha Value
Improvement in Mathematical Understanding	D1-1	0.540	0.706	0.754
	D1-2	0.594	0.685	
	D1-3	0.336	0.788	
	D1-4	0.679	0.665	
	D1-5	0.550	0.703	
Development of Mathematical Thinking	D2-1	0.656	0.807	0.841
	D2-2	0.529	0.839	
	D2-3	0.649	0.808	
	D2-4	0.698	0.794	
	D2-5	0.700	0.793	
Change in Learning Interest	D3-1	0.715	0.830	0.866
	D3-2	0.754	0.823	
	D3-3	0.697	0.836	
	D3-4	0.656	0.845	
	D3-5	0.631	0.851	
Satisfaction and Willingness to Recommend	D4-1	0.592	0.752	0.795
	D4-2	0.744	0.703	
	D4-3	0.380	0.815	
	D4-4	0.611	0.745	
	D4-5	0.576	0.757	

Conclusion

Summary of Findings

According to the content validity and reliability analyses, the instrument demonstrated satisfactory psychometric properties for measuring students' perceived effectiveness of AI-enhanced Advanced Mathematics courses. The content validity assessment conducted by five experts yielded an overall S-CVI/Ave of 0.85, which exceeded the recommended threshold of 0.80. The results indicate that the questionnaire items were generally considered relevant, clear, and representative of the intended constructs. Therefore, the instrument was regarded as possessing satisfactory content validity.

The reliability analysis further demonstrated acceptable to good internal consistency across the four constructs. The Cronbach's Alpha coefficients ranged from 0.754 to 0.866, exceeding the recommended minimum value of 0.70. Most items achieved CITC values above the recommended threshold of 0.40, indicating satisfactory relationships between the individual items and their corresponding constructs.

However, item D1-3 under the construct of Improvement in Mathematical Understanding and item D4-3 under the construct of Satisfaction and Willingness to Recommend obtained CITC values below 0.40. In addition, the deletion of these items resulted in higher Cronbach's Alpha coefficients for their respective constructs. Therefore, these two items were removed from the instrument. After their removal, the final instrument consisted of 18 items distributed across four constructs: Improvement in Mathematical Understanding, Development of Mathematical Thinking, Change in Learning Interest, and Satisfaction and Willingness to Recommend.

Overall, results indicate that the instrument possesses satisfactory content validity and internal consistency reliability. The final 18-item instrument is considered appropriate for assessing students' perceived effectiveness of AI-enhanced Advanced Mathematics courses and may serve as a useful tool for future large-scale empirical research.

Limitations And Future Research

Despite the fact that this study offers initial proof of the instrument's validity and reliability, a number of limitations should be noted. First, only 98 undergraduate students from a small educational setting participated in the pilot study, which may limit how broadly the results may be applied. To further investigate the instrument's robustness, future research should enlist larger and more varied samples from various colleges.

Second, this study mainly focused on content validity and internal consistency reliability. Although these analyses provided initial evidence of instrument quality, further validation using exploratory factor analysis (EFA) and confirmatory factor analysis (CFA) is required to examine the construct validity and factor structure of the instrument.

Future research may also investigate the relationship between students' perceived effectiveness and other learning outcomes, such as academic achievement, engagement, and acceptance of AI-assisted learning.

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Ethics Statement: The research will meet all the general regulations on research ethics. The subjects voluntarily participated in the study and signed the consent form before being interviewed. The privacy and anonymity of the subjects have been guaranteed, and the collected data will only be used for academic research.

Author Contribution Statement: The first author was responsible for the research design, development of the instrument, data collection, data analysis and writing of this paper. The corresponding author directed the research. All the above writers have read and approved the final version of this paper.

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