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An Analytical Study on AI-Based Intelligent Tutoring Systems for Personalised Learning of Mensuration at the Secondary Level

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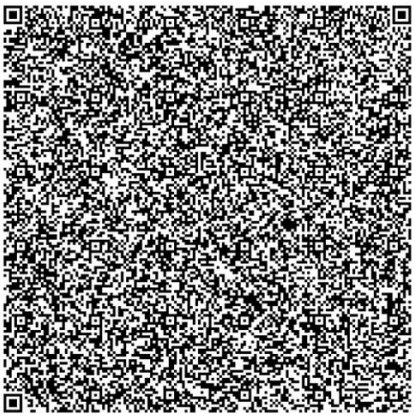
Abstract

The integration of Artificial Intelligence (AI) into educational environments has attracted growing scholarly attention in recent years because of its potential to reshape traditional teaching–learning processes. One of the most significant applications of AI in education is the development of Intelligent Tutoring Systems (ITS), which are capable of providing adaptive instruction and supporting personalised learning experiences for students. In mathematics education, particularly at the secondary level, learners frequently encounter difficulties because many mathematical concepts are abstract in nature. Mensuration, which deals with the measurement of geometric figures such as area, surface area, and volume, is one such topic that often poses challenges for students. These difficulties frequently arise from the need for spatial reasoning and conceptual understanding rather than simple procedural knowledge.

The present analytical study explores the potential role of AI-based Intelligent Tutoring Systems in facilitating personalised learning of mensuration among secondary school students. Drawing upon existing literature related to AI in education, personalised learning environments, and mathematics pedagogy, the study examines how AI-driven systems may support learners by identifying misconceptions, adapting instructional pathways, and providing interactive feedback. The study also discusses the pedagogical considerations involved in integrating AI technologies within secondary mathematics classrooms.

The analysis indicates that AI-based tutoring systems have considerable potential to strengthen conceptual understanding, enhance student engagement, and support individualised instruction in mathematics learning. Recent research further suggests that AI-supported adaptive learning environments can meaningfully improve students' conceptual mastery and engagement in mathematics learning contexts (Zawacki-Richter et al., 2019; Holmes et al., 2022). The study concludes that AI-supported learning environments can significantly contribute to improving students' understanding of mensuration concepts when they are implemented alongside sound pedagogical practices and appropriate curriculum alignment.

Keywords: *Artificial Intelligence (AI), Intelligent Tutoring Systems (ITS), Personalised Learning, Mathematics Education, Mensuration.*



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INTRODUCTION

Technological developments have significantly influenced contemporary educational practices in the twenty-first century, opening new possibilities for teaching and learning. Among emerging technologies, Artificial Intelligence (AI) has received considerable attention because of its ability to simulate certain human cognitive processes such as reasoning, learning, and decision-making (Russell &

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Norvig, 2010). AI-enabled systems are capable of analysing patterns in learner behaviour and providing adaptive responses that support personalised learning experiences.

Recent developments in AI have created new opportunities to enhance instructional practices by enabling adaptive learning environments that respond to the diverse needs of learners (Holmes et al., 2022). The growing interest in AI-supported education has also been reinforced by global educational reforms that emphasise the use of digital technologies to improve the quality and accessibility of education.

Mathematics education is one domain in which technological integration has demonstrated considerable potential. Learning mathematics requires logical reasoning, conceptual clarity, and the ability to apply knowledge in problem-solving situations. However, many students experience difficulties when dealing with mathematical concepts that involve spatial reasoning or abstract thinking.

Mensuration is one such topic within the secondary school mathematics curriculum. It focuses on measuring geometric figures and involves calculations related to area, surface area, and volume. Mastering these concepts requires students to visualise geometric relationships and apply appropriate formulas to different contexts. Despite its practical importance, students often struggle with mensuration because classroom instruction frequently emphasises memorisation of formulas rather than conceptual understanding (Battista, 2007).

Another challenge arises from the diversity of learners present within typical classrooms. Students differ in their prior knowledge, learning pace, and cognitive approaches to problem solving. In traditional classroom settings, teachers often find it difficult to address the individual learning needs of every student due to large class sizes and limited instructional time.

In the Indian educational context, the integration of digital technologies in teaching and learning has received increasing emphasis through policy initiatives such as the **National Education Policy (NEP) 2020**, which encourages the use of Artificial Intelligence and digital tools to improve educational processes (Government of India, 2020). Researchers in India have also pointed out that AI-supported learning environments have the potential to promote personalised learning and improve mathematics achievement among secondary school students (Sharma & Gupta, 2023).

AI-based Intelligent Tutoring Systems (ITS) represent one of the most significant technological developments in this field. These systems are designed to replicate certain aspects of human tutoring by guiding students through problem-solving processes and providing immediate feedback (Woolf, 2010). By analysing students' responses, ITS platforms can identify learning difficulties and provide targeted instructional support. Recent studies also indicate that AI-based intelligent tutoring systems can enhance students' problem-solving abilities and conceptual understanding by offering adaptive feedback and real-time learning analytics (Létourneau, Baker, & Smith, 2025).

Several studies suggest that AI-supported learning environments can improve students' conceptual understanding as well as their engagement in mathematics learning (Holmes, Bialik, & Fadel, 2019; Zawacki-Richter et al., 2019). In this context, exploring the integration of AI-based tutoring systems in mathematics education has become an important area of academic inquiry.

Therefore, the present study analytically examines the potential role of AI-based Intelligent Tutoring Systems in facilitating personalised learning of mensuration at the secondary level.

Review of Literature

The integration of Artificial Intelligence (AI) into education has become an important area of research due to its potential to improve teaching–learning processes and support individualised learning experiences. AI technologies enable educational systems to analyse learner behaviour and adapt instructional content according to the needs of students, thereby creating more personalised learning environments. Luckin, Holmes, Griffiths, and Forcier (2016) argue that AI-supported educational technologies can generate valuable insights into students' learning patterns, enabling instructional systems to respond more effectively to learners' difficulties. Similarly, Holmes, Bialik, and Fadel (2019) emphasise that AI can support more learner-centred educational environments by facilitating adaptive instruction and continuous monitoring of student progress. Recent research also indicates that AI-driven educational technologies can enhance learning outcomes by providing adaptive feedback and personalised learning pathways (Holmes et al., 2022).

One of the most widely discussed applications of AI in education is the development of Intelligent Tutoring Systems (ITS). These systems attempt to simulate the functions of human tutors by guiding learners through problem-solving processes and providing immediate feedback. Anderson, Corbett, Koedinger, and Pelletier (1995) introduced the concept of **cognitive tutors**, which assist students by diagnosing errors and offering hints during problem solving.

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Research has shown that ITS platforms can significantly improve learning outcomes, particularly in subjects that require structured reasoning and step-by-step problem solving. In a comprehensive meta-analysis, VanLehn (2011) found that intelligent tutoring systems often produce learning gains comparable to those achieved through one-to-one human tutoring. Graesser, Chipman, Haynes, and Olney (2005) also demonstrated the effectiveness of systems such as **AutoTutor**, which support interactive learning through dialogue-based feedback and adaptive instruction. More recent systematic reviews indicate that AI-based tutoring systems have become increasingly effective in supporting mathematics learning through adaptive problem-solving guidance (Zawacki-Richter et al., 2019).

Personalised learning has emerged as a central concept in contemporary education, particularly with the rapid advancement of digital learning technologies. Personalised learning environments allow instructional content to be adjusted according to learners' pace, prior knowledge, and cognitive abilities. Pane, Steiner, Baird, and Hamilton (2017) reported that technology-supported personalised learning initiatives have demonstrated positive effects on student achievement and engagement. Digital technologies can also support deeper learning by enabling students to interact with concepts rather than passively receiving information (Dede, 2014). Within mathematics education, technological tools can promote conceptual understanding by offering dynamic visual representations of mathematical ideas (Kaput, 1992). Recent studies suggest that AI-supported mathematics learning platforms can significantly improve students' conceptual understanding by enabling interactive visualisation and personalised problem-solving pathways (Hwang & Tu, 2024).

Understanding geometric concepts such as mensuration requires spatial reasoning and visualisation skills, which many students find difficult to develop. Research suggests that learners frequently rely on memorising formulas instead of understanding the relationships between geometric dimensions (Battista, 2007). Interactive digital learning environments can help address this issue by providing visual representations that allow students to manipulate geometric figures and explore mathematical relationships. Clements and Sarama (2014) note that technology-supported learning environments can enhance students' spatial reasoning abilities and promote deeper conceptual understanding of geometry.

Within the Indian educational context, several researchers have emphasised the importance of integrating digital technologies and AI-supported learning systems into mathematics classrooms to address diverse learner needs (Sharma & Gupta, 2023). Studies conducted in Indian secondary schools indicate that adaptive learning platforms can effectively support individualised instruction and improve students' conceptual understanding of mathematical topics (Kumar & Singh, 2022). More recent research also suggests that AI-supported adaptive learning platforms have the potential to enhance mathematics learning outcomes by providing instruction tailored to students' learning levels (Kumar & Sharma, 2024).

Despite these promising developments, research focusing specifically on the role of AI-based Intelligent Tutoring Systems in supporting the learning of mensuration at the secondary level remains relatively limited. This indicates the need for further analytical and empirical studies examining how AI-based tutoring systems can enhance conceptual understanding of mensuration and facilitate personalised learning in mathematics education.

Methodology

The present study adopts an analytical research approach based on systematic examination and synthesis of existing literature related to Artificial Intelligence in education, intelligent tutoring systems, personalised learning environments and mathematics pedagogy.

Relevant academic sources were identified through scholarly journals, books, and research reports focusing on educational technology and mathematics education. The selected literature was analysed thematically to explore three main aspects:

1. The role of Artificial Intelligence in supporting personalised learning environments
2. The effectiveness of intelligent tutoring systems in mathematics education
3. Conceptual challenges associated with learning mensuration at the secondary level

The findings derived from this thematic analysis were synthesised to develop an analytical understanding of how AI-based tutoring systems can support personalised learning of mensuration.

Analysis and Findings

The analysis of existing literature reveals several significant insights regarding the role of AI-based Intelligent Tutoring Systems in mathematics education. AI-supported tutoring systems enable personalised learning experiences by adapting instructional content according to learners' progress. These systems continuously monitor students' responses and adjust learning pathways to address individual needs. ITS platforms also provide immediate feedback

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during problem-solving activities. Such feedback allows students to identify errors and correct misconceptions in real time. Immediate feedback has been shown to improve learning efficiency and strengthen conceptual understanding. AI-based systems can also effectively identify patterns of misconceptions in students' responses. For instance, in mensuration learning, students often confuse formulas related to surface area and volume. Intelligent tutoring systems can detect such patterns and provide targeted explanations to clarify misunderstandings. The Interactive digital environments integrated within AI-based systems can enhance student engagement. Visual simulations of geometric figures allow learners to explore relationships between dimensions and measurements. Finally, AI technologies generate learning analytics that help teachers monitor students' progress and identify areas where additional instructional support may be needed.

Discussion

The findings of this study highlight the significant potential of Artificial Intelligence in transforming mathematics education. AI-based tutoring systems provide opportunities to complement traditional classroom instruction by offering individualised learning support. In the context of mensuration learning, AI technologies can provide dynamic visualisations that help students understand geometric relationships more effectively. By enabling learners to interact with geometric models, digital learning environments encourage exploration and conceptual reasoning. However, the successful implementation of AI technologies in education requires careful consideration of pedagogical principles. Technology should be integrated into instructional practices in ways that support meaningful learning rather than simply replacing traditional teaching methods. Teacher preparedness is also essential for effective technology integration. Educators must be trained to use AI-based learning tools and interpret learning analytics generated by these systems. Additionally, issues related to digital infrastructure and accessibility should be addressed to ensure that all learners benefit from technological innovations in education.

Conclusion

Artificial Intelligence has the potential to significantly enhance mathematics education by enabling personalised learning environments that respond to individual learner needs. AI-based Intelligent Tutoring Systems can provide adaptive instruction, immediate feedback, and interactive learning experiences that support deeper conceptual understanding. The analytical examination presented in this study suggests that AI-supported tutoring systems can play a crucial role in improving students' comprehension of mensuration concepts at the secondary level. By integrating visualisation tools, adaptive feedback, and diagnostic assessment, AI technologies can help learners overcome conceptual difficulties and develop stronger mathematical reasoning skills. Future research should focus on designing and empirically evaluating AI-based tutoring systems specifically developed for secondary mathematics education. Such investigations would provide valuable insights into the effectiveness of AI technologies in supporting personalised learning within diverse educational contexts.

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