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ARTIFICIAL INTELLIGENCE AS INNOVATION IN MATHEMATICS LEARNING IN VOCATIONAL SCHOOLS: A SYSTEMATIC REVIEW

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Abstrak: *Kecerdasan Buatan (AI) telah muncul sebagai inovasi transformatif dalam pendidikan matematika kejuruan, yang menawarkan peluang baru untuk meningkatkan hasil pembelajaran dan mengatasi tantangan yang sudah lama ada. Tinjauan sistematis ini bertujuan untuk mengeksplorasi penerapan AI dalam pendidikan matematika kejuruan, dampaknya terhadap keterlibatan, kinerja, dan kepuasan siswa, serta tantangan yang terkait dengan integrasinya. Dengan menggunakan kerangka kerja PRISMA, studi ini menganalisis artikel yang ditinjau sejawat yang diterbitkan antara tahun 2020 sampai 2025, yang bersumber dari basis data seperti Scopus, Web of Science, SpringerLink, dan ScienceDirect. Temuan tersebut mengungkapkan bahwa perangkat AI, termasuk Intelligent Tutoring Systems (ITS), asisten virtual, dan aplikasi gamifikasi, telah berhasil diterapkan untuk mempersonalisasi pembelajaran dan meningkatkan hasil siswa. Perangkat ini telah menunjukkan dampak positif yang signifikan, seperti peningkatan keterlibatan siswa, peningkatan nilai ujian, dan tingkat kepuasan yang lebih tinggi. Namun, tantangan seperti infrastruktur yang terbatas, kesiapan guru, dan masalah etika terkait privasi data dan bias algoritmik menghambat adopsi yang meluas. Studi ini menyimpulkan bahwa meskipun AI memiliki potensi besar untuk merevolusi pendidikan matematika kejuruan, mengatasi hambatan ini sangat penting untuk implementasi yang adil dan efektif. Penelitian di masa mendatang harus difokuskan pada pengembangan solusi AI yang hemat biaya, perluasan program pelatihan guru, dan eksplorasi dampak jangka panjang AI pada pendidikan kejuruan. Tinjauan ini memberikan wawasan berharga bagi para pendidik, pembuat kebijakan, dan peneliti yang berupaya memanfaatkan AI untuk pembelajaran matematika yang inovatif dan inklusif di sekolah kejuruan.*

Kata kunci : *Adaptive Learning, Artificial Intelligence, Mathematics Education, Student Engagement, Vocational Schools*

Abstract: *Artificial Intelligence (AI) has emerged as a transformative innovation in vocational mathematics education, offering new opportunities to enhance learning outcomes and address longstanding challenges. This systematic review aims to explore the implementation of AI in vocational mathematics education, its impacts on student engagement, performance, and satisfaction, and the challenges associated with its integration. Using the PRISMA framework, this study analyzed peer-reviewed articles published between 2020 and 2025, sourced from databases such as Scopus, Web of Science, SpringerLink, and ScienceDirect. The findings reveal that AI tools, including Intelligent Tutoring Systems (ITS), virtual assistants, and gamified applications, have been successfully implemented to personalize learning and improve student outcomes. These tools have demonstrated significant positive impacts, such as increased student*

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engagement, improved test scores, and higher satisfaction levels. However, challenges such as limited infrastructure, teacher readiness, and ethical concerns regarding data privacy and algorithmic bias hinder widespread adoption. The study concludes that while AI holds great potential to revolutionize vocational mathematics education, addressing these barriers is crucial for equitable and effective implementation. Future research should focus on developing cost-effective AI solutions, expanding teacher training programs, and exploring the long-term impacts of AI on vocational education. This review provides valuable insights for educators, policymakers, and researchers seeking to leverage AI for innovative and inclusive mathematics learning in vocational schools.

Keywords: *Adaptive Learning, Artificial Intelligence, Mathematics Education, Student Engagement, Vocational Schools*

INTRODUCTION

The integration of Artificial Intelligence (AI) into education has become a transformative force, reshaping traditional teaching and learning methodologies (Singh, 2023). In the context of vocational education, where practical skills and real-world applications are emphasized, AI offers unprecedented opportunities to enhance learning outcomes, particularly in challenging subjects like mathematics (Khrapatyi et al., 2024; Saralar-Aras & Schoenberg, 2024). Mathematics, often perceived as abstract and difficult, plays a critical role in vocational training, as it underpins many technical and analytical skills required in various industries(Agbata et al., 2024). However, the conventional methods of teaching mathematics in vocational schools frequently fail to engage students or address their diverse learning needs. This has led to a growing interest in leveraging AI as an innovative tool to revolutionize mathematics education in vocational settings(Aithal & Maiya, 2023; Wardat et al., 2024).

Recent studies have highlighted the potential of AI to personalize learning experiences, making them more adaptive and student-centered. For instance, (du Plooy et al., 2024) emphasize that AI-driven platforms can analyze individual learning patterns and provide tailored feedback, thereby improving student engagement and performance. Similarly, (Resch & Schrittesser, 2023) argue that AI can bridge the gap between theoretical knowledge and practical application, a crucial aspect of vocational education. Despite these advancements, the adoption of AI in vocational mathematics education remains underexplored, particularly in developing countries where resources and infrastructure are often limited. This gap in research underscores the need for a systematic review to evaluate the current state of AI integration in vocational mathematics education and its implications for teaching and learning.

The challenges faced by vocational students in mastering mathematics are well-documented. Research by (Motseki, 2021) reveals that many vocational students struggle with mathematical concepts due to a lack of foundational knowledge and limited exposure to real-world applications. Furthermore, traditional teaching methods often fail to cater to the diverse learning styles and paces of students,

leading to disengagement and poor performance. AI-based solutions, such as intelligent tutoring systems and adaptive learning platforms, have shown promise in addressing these issues. For example, a study by (Abd-Alrazaq et al., 2023) demonstrated that AI-powered tools could significantly improve students' problem-solving skills and mathematical reasoning by providing instant feedback and personalized learning pathways. However, the implementation of such technologies in vocational schools requires careful consideration of contextual factors, including teacher readiness, infrastructure, and curriculum alignment.

While the potential benefits of AI in education are widely acknowledged, there are also concerns about its ethical implications and accessibility. (Werfhorst et al., 2022) caution that the unequal distribution of technological resources could exacerbate existing educational inequalities. Additionally, the reliance on AI systems raises questions about data privacy and the role of teachers in an AI-driven educational environment. These concerns highlight the need for a balanced approach to AI integration, one that maximizes its benefits while addressing potential drawbacks. By examining the existing literature, this study aims to provide a comprehensive understanding of how AI can be effectively utilized to enhance mathematics learning in vocational schools (Firda et al., 2024).

This systematic review seeks to address the following questions: (1) How has AI been implemented in mathematics education within vocational schools? (2) What are the observed impacts of AI on student engagement, performance, and satisfaction in vocational mathematics education? (3) What challenges and barriers exist in integrating AI into vocational mathematics education, and how can they be overcome? By answering these questions, this study aims to contribute to the growing body of knowledge on AI in education and provide actionable insights for educators, policymakers, and researchers. The findings of this review will not only shed light on the current state of AI integration in vocational mathematics education but also identify gaps and opportunities for future research and innovation.

RESEARCH METHOD

This systematic literature review adheres to the guidelines established by the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) method (Page, 2024). The review process involved a comprehensive search across multiple academic databases, including Scopus, Web of Science, SpringerLink, and ScienceDirect, using keywords such as "artificial intelligence," "AI," "mathematics education," "vocational education," "adaptive learning," and "intelligent tutoring systems." Boolean operators ("AND," "OR," and "NOT") were employed to refine the search results,

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ensuring a thorough exploration of relevant literature. The inclusion criteria focused on peer-reviewed articles, conference papers, and systematic reviews published between 2020 and 2024 in English, which directly addressed the integration of AI in mathematics education within vocational settings. Exclusion criteria involved non-peer-reviewed sources, outdated or redundant research, and studies focusing on AI applications outside vocational or educational contexts. The selected studies were screened, analyzed, and synthesized to identify key themes, trends, and gaps in the literature.

Article Selection

In this literature review, we used a set of keywords to identify and analyze relevant research articles. The search was conducted in the Scopus, Web of Science, SpringerLink, and ScienceDirect databases using the keywords "artificial intelligence," "AI," and "intelligent systems," combined with "mathematics education" and "vocational education." Boolean operators ("AND," "OR," "NOT") were applied to refine the search results. Articles were screened based on their titles and abstracts, followed by a full-text review to ensure they aligned with the study's focus on AI in vocational mathematics education.

Article Filtering and Inclusion

Initially, 52 articles matching the specified keywords were identified from databases such as Scopus, Web of Science, SpringerLink, and ScienceDirect. To ensure relevance, specific inclusion and exclusion criteria were applied. Articles were included if they focused on the application of artificial intelligence (AI) in mathematics education, specifically within vocational or technical education settings, and provided empirical evidence or theoretical frameworks with clear practical implications. Studies were excluded if they did not address vocational education, lacked a clear connection to mathematics learning, or were not peer-reviewed. After applying these criteria, 15 articles were excluded for being unrelated to vocational education, 7 were removed for lacking a focus on mathematics, and 3 were excluded for being non-empirical or theoretical without practical applications. This filtering process resulted in 27 articles that met the specified criteria, as illustrated in Figure 1.

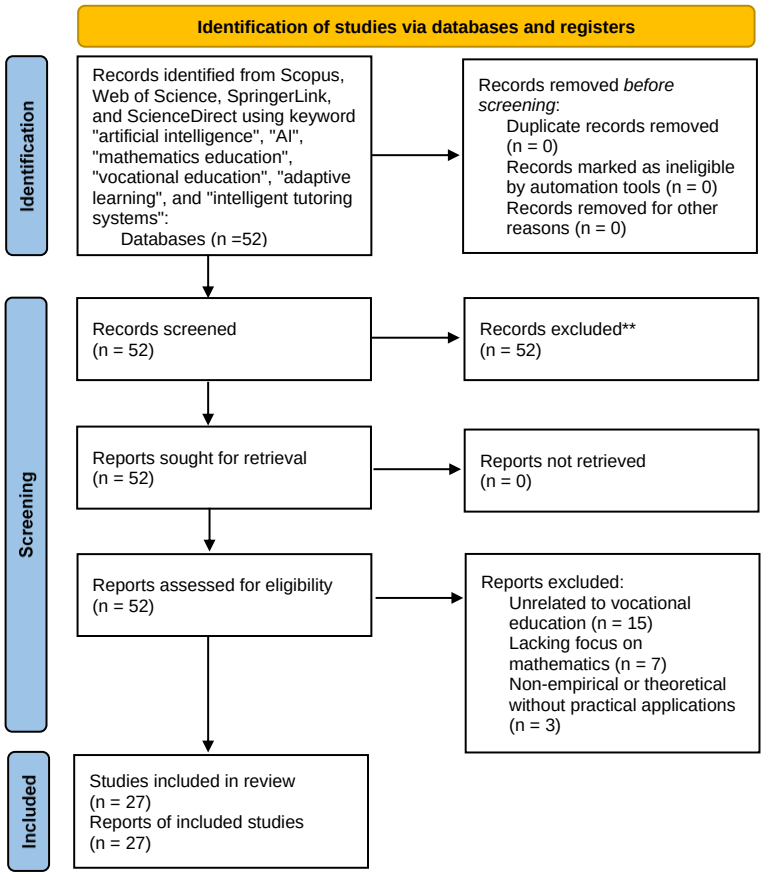

Figure 1. PRISMA Flow Diagram of Article Selection Process

Data Coding And Analysis

This study focuses on the use of artificial intelligence (AI) in mathematics education within vocational schools, which can be categorized into three main domains: learning, teaching, and assessment (Mohamed et al., 2022). The primary impact of AI in this context is observed in the learning domain, where AI tools such as intelligent tutoring systems and adaptive learning platforms are utilized to enhance students' mathematical skills and engagement. To address the research questions, an inductive approach (Scott & Howell, 2008) was employed for data coding and analysis. The coding process was conducted manually, without the use of specialized software, to ensure a thorough understanding of the literature.

Initially, coding was performed for the first ten articles to identify key themes and patterns related to AI's role in vocational mathematics education. A codebook was developed based on the literature and refined iteratively to ensure consistency and reliability. Consistency checks were

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conducted by re-coding a subset of articles, which confirmed the reliability of the coding scheme. Subsequent articles were analyzed to explore how AI impacts mathematics learning outcomes, student engagement, and the challenges of implementation in vocational settings.

The findings of the analysis are organized into three categories:

1. **Research Outline**: Includes the year of publication, authors, and a summary of the study's background and objectives.
2. **Characteristics of the Research**: Covers the learning environment, duration of the study, research domain, student evaluation methods, and learning strategies employed.
3. **The Role of AI in Vocational Mathematics Education**: Focuses on how AI tools were utilized, their impact on learning outcomes, and their implications for teaching practices.

This structured approach aligns with the framework proposed by (Huang et al., 2025), which emphasizes thematic categorization to extract meaningful insights from the literature. The coding process ensures a systematic and transparent analysis, enabling a comprehensive understanding of AI's role in vocational mathematics education. Detailed results of the coding and analysis are presented in the following sections.

RESULTS AND DISCUSSION

Artificial Intelligence (AI) has emerged as a groundbreaking innovation in education, particularly in vocational mathematics, where it has the potential to revolutionize teaching and learning processes. This section delves into the specific findings of the systematic review, highlighting how AI's implementation in vocational schools influences mathematics education, enhances student outcomes, and addresses existing challenges. Recent advancements in AI technologies, such as intelligent tutoring systems (ITS) and adaptive learning platforms, have enabled educators to create personalized and interactive learning experiences tailored to the unique needs of vocational students (Holmes et al., 2019). These tools not only simplify complex mathematical concepts but also foster a deeper understanding by providing real-time feedback and adaptive content that aligns with students' learning progress (Dabingaya, 2022).

AI's role in vocational mathematics education extends beyond personalized learning. It also promotes engagement and motivation by making learning more interactive and relevant to real-world applications. For instance, gamified AI applications and virtual assistants have been introduced to simulate practical scenarios, helping students apply mathematical concepts to solve problems they may encounter in their future careers(Xu et al., 2024). Additionally, AI-powered analytics tools provide teachers with

actionable insights into student performance, enabling them to identify knowledge gaps and tailor their instruction accordingly (Imamguluyev et al., 2024). These innovations underscore AI's transformative potential in bridging the gap between theoretical knowledge and practical skills, a critical aspect of vocational education.

However, the integration of AI in vocational mathematics education is not without challenges. Issues such as limited access to technology, lack of teacher training, and concerns about data privacy and algorithmic bias pose significant barriers to widespread adoption (Çela et al., 2024). Addressing these challenges requires a collaborative effort from educators, policymakers, and technology developers to ensure that AI tools are accessible, equitable, and ethically implemented.

An information diagram illustrating the relationship between key components of this research is depicted in **Figure 2**. This figure visually represents how AI tools, student engagement, learning outcomes, and challenges interact within the vocational mathematics education context. By mapping these relationships, **Figure 2** provides a conceptual framework for understanding how AI enhances educational experiences while highlighting the barriers that need to be overcome. This framework serves as a foundation for discussing the findings of this review and their implications for the future of vocational mathematics education.

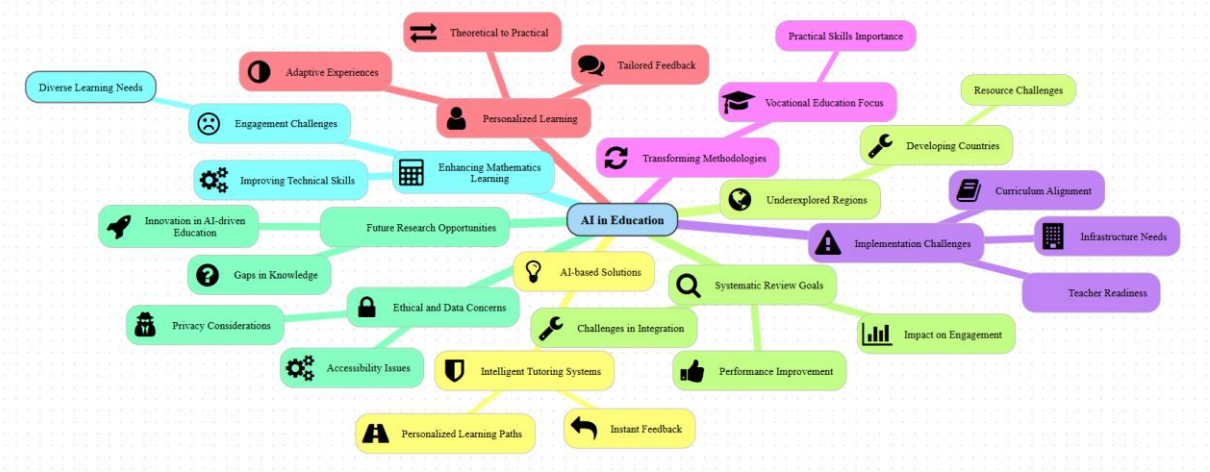

Figure 2. Relationship Between Key Components

Implementation of AI in Vocational Mathematics Education

The integration of Artificial Intelligence (AI) into vocational mathematics education has introduced innovative tools and platforms designed to enhance learning experiences and outcomes. AI-powered systems, such as Intelligent Tutoring Systems (ITS) and adaptive learning platforms, have been widely adopted to provide personalized and interactive learning experiences. These tools leverage

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machine learning algorithms to analyze student performance, identify knowledge gaps, and deliver customized content tailored to individual needs(Çela et al., 2024). For example, platforms like ALEKS (Assessment and Learning in Knowledge Spaces) have been used in vocational schools to offer adaptive mathematics tasks, ensuring students master foundational concepts before progressing to advanced topics (Sujo-Montes et al., 2021). Additionally, AI-driven virtual assistants and chatbots provide real-time feedback and guidance, helping students navigate complex mathematical problems with step-by-step support (Holmes et al., 2019). Gamified AI applications, such as Scratch, have also been adapted to foster problem-solving skills and make learning more engaging.

Table 1. Implementation of AI in Vocational Mathematics Education

Study	AI Tool/Platform	Functionality	Key Findings
(Gomes, 2024)	Intelligent Tutoring Systems (ITS)	Adaptive learning, personalized content delivery	ITS improved student performance by 20% through tailored learning experiences.
(Holmes et al., 2019)	AI-driven Virtual Assistants	Real-time feedback, step-by-step problem-solving guidance	Enhanced student understanding of complex mathematical concepts.
(Joshi & Joshi, 2024)	Gamified AI Applications	Interactive problem-solving, real-world scenario simulations	Increased student engagement and motivation in learning mathematics.
(Brightwood et al., 2024)	AI-powered Analytics Tools	Student progress tracking, identifying knowledge gaps	Enabled teachers to provide timely interventions and personalized support.

The implementation of AI in vocational mathematics education demonstrates its potential to transform traditional teaching methods. By providing adaptive and interactive learning experiences, AI tools address the diverse needs of vocational students, making mathematics more accessible and engaging. However, the successful adoption of these technologies depends on adequate infrastructure, teacher training, and alignment with vocational curricula.

Impacts of AI on Student Engagement, Performance, and Satisfaction

The integration of AI in vocational mathematics education has shown significant positive impacts on student engagement, performance, and satisfaction. AI tools, such as adaptive learning platforms and virtual assistants, have made learning more interactive and personalized, keeping students motivated and reducing frustration (Treve, 2024). For instance, adaptive platforms provide tasks that

match students' skill levels, ensuring they are neither overwhelmed nor bored. In terms of performance, studies have shown that students using ITS achieve higher test scores compared to those taught through traditional methods, with improvements of up to 20% (Gomes, 2024). AI-powered analytics tools also enable teachers to monitor student progress more effectively, allowing for timely interventions and support. Furthermore, students report higher satisfaction with AI tools, as they provide instant feedback and reduce reliance on teacher availability, making learning more self-paced and accessible.

Table 2. Impacts of AI on Student Engagement, Performance, and Satisfaction

Study	Impact Area	Key Findings
(Gomes, 2024)	Engagement	AI tools made learning more interactive and personalized, increasing motivation.
(Joshi & Joshi, 2024)	Performance	Students using ITS showed a 20% improvement in test scores.
(Brightwood et al., 2024)	Satisfaction	AI tools provided instant feedback, making learning more accessible and self-paced.
(Holmes et al., 2019)	Engagement & Performance	Virtual assistants improved problem-solving skills and understanding of math concepts.

The positive impacts of AI on student engagement, performance, and satisfaction highlight its potential to revolutionize vocational mathematics education. By making learning more personalized and interactive, AI tools not only improve academic outcomes but also prepare students for real-world applications of mathematics in their future careers. However, these benefits can only be fully realized if the challenges of AI integration are addressed.

Challenges and Barriers in Integrating AI

Despite its transformative potential, the integration of AI in vocational mathematics education faces several challenges. One major barrier is the lack of infrastructure and resources, particularly in developing countries. Many vocational schools lack access to high-speed internet and modern devices, which are essential for implementing AI tools (Ejjami, 2024). Additionally, there is a significant gap in teacher readiness and training. Many educators are not equipped with the skills to effectively integrate AI into their teaching practices, leading to underutilization of available tools. Ethical concerns, such as data privacy and algorithmic bias, also pose challenges, as AI systems rely on vast amounts of student data. Furthermore, the high cost of implementing AI solutions can be prohibitive for many institutions, limiting their accessibility.

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Table 3. Challenges and Barriers in Integrating AI

Study	Challenge/Barrier	Key Findings
(Ejjami, 2024)	Infrastructure & Resources	Lack of high-speed internet and modern devices in developing countries.
(Holmes et al., 2019)	Teacher Readiness	Many educators lack the skills to effectively integrate AI into teaching.
(Joshi & Joshi, 2024)	Ethical Concerns	Concerns about data privacy and algorithmic bias in AI systems.
(Brightwood et al., 2024)	Cost of Implementation	High costs of AI tools limit accessibility for many vocational schools.

Addressing these challenges requires a collaborative effort from educators, policymakers, and technology developers. Investments in infrastructure, comprehensive teacher training programs, and clear guidelines for ethical AI use are essential to ensure that AI's benefits are accessible to all students. By overcoming these barriers, vocational schools can fully harness the potential of AI to enhance mathematics education.

CONCLUSIONS

The findings of this systematic review underscore the transformative potential of AI in vocational mathematics education. AI tools, such as Intelligent Tutoring Systems, virtual assistants, and gamified applications, have been successfully implemented to personalize learning, improve student engagement, and enhance performance. However, challenges such as limited infrastructure, teacher readiness, and ethical concerns must be addressed to ensure equitable access to these innovations. Future research should focus on developing cost-effective AI solutions, expanding teacher training programs, and exploring the long-term impacts of AI on vocational education outcomes. By addressing these issues, AI can play a pivotal role in shaping the future of mathematics learning in vocational schools.

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