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iJEP International Journal of Engineering Pedagogy

iJEP | eISSN: 2192-4880 | Vol. 15 No. 4 (2025) | OPEN ACCESS

https://doi.org/10.3991/ijep.v15i4.52797

PAPER

Assessing the Effectiveness of Personalized Adaptive Learning in Teaching Mathematics at the College Level

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ABSTRACT

Personalized adaptive learning tailors' education to each student's unique needs by adjusting materials, tasks, and feedback based on their individual skill levels and progress. This paper details the development and implementation of a personalized adaptive learning platform designed to assess students' mathematical abilities and offer customized exercises that align with their strengths and areas for improvement. A pilot study conducted with 118 students at Aktobe Higher Polytechnic College (Kazakhstan) demonstrated that this approach led to significant improvements in academic performance, engagement, and motivation compared to traditional teaching methods. By providing individualized learning paths and real-time feedback, the platform enhanced students' problem-solving abilities and overall understanding of mathematics. This paper also explores the platform's design, adaptive algorithms, and the measurable impact on student outcomes, highlighting the potential of personalized adaptive learning to transform educational practices and improve learning effectiveness in diverse academic environments.

KEYWORDS

personalized adaptive learning, individualized education, mathematics teaching, adaptive learning platforms, student performance, learning algorithms, educational technology

1 INTRODUCTION

The rise of advanced educational technologies has brought significant opportunities to enhance the learning experience and foster student development. As technology evolves and becomes more integrated into the classroom, educational practices are shifting towards more effective and individualized approaches. Emerging technologies such as augmented reality (AR) [1], the Internet of Things (IoT) [2], or any other digital technologies [3] are already demonstrating potential to enhance engagement and learning outcomes by offering more interactive and collaborative learning environments adaptive learning, in particular, offers a promising future for addressing the diverse needs of students by tailoring instruction to their unique learning profiles [4].

Zulpykhar, Z., Kariyeva, K., Sadvakassova, A., Zhilmagambetova, R., Nariman, S. (2025). Assessing the Effectiveness of Personalized Adaptive Learning in Teaching Mathematics at the College Level. *International Journal of Engineering Pedagogy (iJEP)*, 15(4), pp. 4–22. https://doi.org/10.3991/ijep.v15i4.52797

Article submitted 2024-10-10. Revision uploaded 2025-02-13. Final acceptance 2025-02-13.

Educational institutions and platforms are already incorporating adaptive learning elements, demonstrating the potential for widespread implementation in the future [5], [6].

Personalized adaptive learning is a powerful tool that adjusts instructional materials and tasks based on a student's knowledge, learning pace, and performance [7], [8]. Adaptive learning can be implemented through both technology-driven systems and non-technological approaches. Technology-based adaptive learning leverages tools such as algorithms, data analytics, and real-time feedback to dynamically customize learning paths. Examples include platforms such as Math Mentor, which analyze student performance and tailor tasks accordingly, or widely used systems such as Dream ox Learning and Khan Academy [9]. On the other hand, non-technological adaptive learning relies on methods such as differentiated instruction, where teachers manually adjust materials, pacing, and teaching strategies to meet the needs of individual students [10]. Both approaches aim to enhance learning outcomes by aligning instructional methods with the unique profiles of learners, with technology offering greater scalability and precision in adapting to diverse needs [11].

This approach differs from traditional, one-size-fits-all curricula by using data-driven insights to offer customized learning experiences. For example, platforms such as Dream Box Learning enable students to engage with mathematics tasks specifically tailored to their skill levels, allowing them to optimize their learning time and focus on areas requiring development, such as algebraic thinking or geometric reasoning [12], [13]. Additionally, platforms such as Khan Academy provide real-time dashboards for teachers, allowing them to monitor student progress and adjust their instructional strategies accordingly. These platforms enable educators to focus on students' problem-solving techniques, critical thinking skills, and other areas where they may struggle, fostering a more targeted and effective learning environment [14], [15].

Furthermore, personalized adaptive learning systems play a key role in developing self-organization and self-regulation skills, competencies that are essential in modern education [16], [17]. A critical component of these competencies is autonomous learning, which refers to a learner's ability to take responsibility for their educational progress by setting goals, monitoring progress, and reflecting on outcomes. Adaptive learning platforms, such as Math Mentor and DreamBox Learning, inherently support the development of autonomous learning by providing tools for goal-setting, self-assessment, and real-time feedback. These features encourage students to take an active role in their learning process, transitioning from passive recipients of knowledge to self-directed learners capable of adapting to new challenges independently. This emphasis on autonomy is crucial for preparing students to succeed in dynamic and complex learning environments, both academic and professional [13], [18], [19].

Mathematics, in particular, benefits greatly from adaptive learning platforms. Students often face challenges mastering abstract mathematical concepts, and the ability to customize learning materials and teaching methods can help them build foundational knowledge more effectively [20]. With adaptive online platforms, students can access personalized explanations and learning resources that match their understanding, leading to a more efficient learning process. Studies have shown that students who use personalized adaptive systems demonstrate higher levels of learning, motivation, and satisfaction compared to those in traditional learning environments [21].

The growing demand for personalized learning underscores the fact that each student possesses unique learning needs and preferences. Traditional educational systems, which rely on standardized curricula, are often unable to meet the varying requirements of individual students. However, personalized learning platforms can complement traditional learning methods by providing individualized support alongside standardized instruction [18]. For instance, while traditional classroom settings excel at fostering group discussions and collaborative learning, personalized platforms such as Math

Mentor and Khan Academy offer tailored exercises and feedback that address individual knowledge gaps [19]. This hybrid approach allows educators to maintain the benefits of traditional teaching while leveraging technology to enhance individual student outcomes, resulting in a more balanced and effective educational experience [20]. Integrating these platforms into traditional curricula can empower teachers to provide differentiated instruction without overburdening their workload, making education more inclusive and adaptive to diverse learning needs [21]. Personalized adaptive learning addresses this issue by offering a more flexible and responsive educational model. In addition to improving learning outcomes, this approach helps students develop critical thinking, problem-solving skills, and the ability to learn independently [22], [23]. By turning education into a more engaging and interactive process, personalized adaptive learning allows each student to reach their full potential and achieve better results.

Educational institutions that implement personalized adaptive learning strategies are poised to significantly improve the quality of education they offer. These institutions can better facilitate academic progress, enhance student motivation, and prepare students with competencies that are in high demand in today's labor market. Given the rapidly evolving nature of the workforce, adaptive learning is crucial in ensuring that students acquire the necessary skills to meet the demands of modern industries.

In this context, our study aims to develop and implement a personalized adaptive learning system in a college setting that effectively meets the needs of each student. The objective is to increase academic performance and student engagement while improving the overall quality of education. Specifically, we aim to explore the theoretical foundations and practical applications of personalized adaptive learning in higher education.

The study has several key goals:

1. To examine existing theoretical approaches to personalized adaptive learning and their relevance in the context of college education.
2. To analyze various adaptive educational platforms and tools, including learning management systems, and assess their applicability.
3. To develop and implement new educational strategies and tools in the college curriculum.
4. To conduct experimental studies comparing the learning outcomes of students in traditional educational settings with those using personalized adaptive learning platforms.

In the following sections, we will present a research model that outlines how the effectiveness of personalized adaptive learning will be studied and evaluated. The paper will also provide recommendations for future applications and improvements in adaptive learning practices within educational institutions.

2 LITERATURE REVIEW

The personalized adaptive learning system continues to evolve, representing a promising direction in the field of education. As technology advances, adaptive systems are becoming increasingly sophisticated, tailoring educational experiences to the unique needs of each student. Several studies have explored different approaches to implementing and refining these systems, highlighting their potential in both formal and informal learning settings.

For instance, the study "Rule-based Adaptive User Interface for Adaptive E-learning System" evaluates the effectiveness of an architectural framework for adaptive e-learning [24]. The authors conducted experiments comparing learning outcomes between students who used this adaptive framework and those who followed traditional learning methods, finding that personalized systems significantly enhanced student performance. Building on this, the paper "Towards Personalized Adaptive Learning in e-Learning Recommender Systems" delves into how adaptive learning can also address educational inequities by providing tailored support to students from low-income or vulnerable backgrounds [25]. This study emphasizes the role of artificial intelligence (AI) and data analysis in identifying individual student needs. These technologies enable the creation of personalized learning paths tailored to each learner's specific strengths and weaknesses. Adaptive learning systems, such as Math Mentor, utilize AI algorithms to analyze student performance in real-time, providing targeted feedback and dynamically adjusting the difficulty of tasks. Compared to traditional learning, where instruction often follows a one-size-fits-all model, adaptive learning offers significant advantages, including increased engagement, faster learning progression, and more precise identification of knowledge gaps. Table 1 illustrates the key benefits of adaptive learning platforms compared to traditional teaching methods.

Table 1. Comparison of adaptive learning and traditional learning

Feature	Adaptive Learning	Traditional Learning
Personalization	Tailored to individual student needs based on real-time performance data.	Uniform curriculum for all students, lacking individual customization.
Engagement	Interactive tools and dynamic feedback maintain high engagement.	Engagement depends largely on teacher-led activities.
Pacing	Self-paced learning allows students to progress at their own speed.	Fixed pacing, determined by the teacher or syllabus.
Feedback	Real-time, data-driven feedback for continuous improvement.	Feedback is often delayed, provided through periodic assessments.
Scalability	Easily scalable with minimal teacher intervention required for adjustments.	Limited scalability due to dependence on teacher resources.

The tools in Table 2 exhibit shared characteristics and underlying themes, demonstrating the versatility and impact of adaptive learning systems. GIFT [26] uses modular architecture and meta-adaptation, similar to Moodle LMS [27], which dynamically personalizes learning paths. Both systems emphasize real-time adjustments to meet individual student needs. Meanwhile, SRL-RuAS [28] employs rule-based systems for adaptive scaffolding, aligning with PlayPosit's [29] focus on interactive and student-centered support through multimedia engagement.

Table 2. Comparative overview of adaptive learning tools and platforms

Study	Adaptive Tool/Platform	Technological Features	Learning Context	Outcomes Observed
[26]	Generalized Intelligent Tutoring Framework (GIFT)	Modular architecture, meta-adaptation, reinforcement learning	Higher education, K-12, military training	Enhanced personalization, improved scalability, real-time optimization of learning tasks
[29]	Adaptive Interactive Video Platform (PlayPosit)	AI-driven learning analytics, interactive video elements	Classroom-based environmental education	Increased usability (SUS score: 75.4), positive student engagement (flow scores >3.8)

(Continued)

Table 2. Comparative overview of adaptive learning tools and platforms *(Continued)*

Study	Adaptive Tool/Platform	Technological Features	Learning Context	Outcomes Observed
[27]	Adaptive Learning Model for Moodle LMS	Personalized paths based on prior knowledge, dynamic monitoring, SCORM compatibility	Higher education (IT courses)	Higher grades (+0.87), improved engagement, reduced time spent on courses
[28]	Rule-Based Self-Regulated Learning Assistance Scheme (SRL-RuAS)	Adaptive scaffolding strategies, personalized diagnostic reports, real-time learning feedback	Computer software training	Improved learning outcomes (+18.2% posttest improvement), high user satisfaction (4.25/5)

Engagement and usability are central to these tools. PlayPosit demonstrates high usability with a System Usability Score (SUS) of 75.4, while Moodle LMS achieves improved learner interaction, as evidenced by grade increases (+0.87) and reduced time spent on courses. These findings highlight the role of adaptive systems in creating engaging environments tailored to users' needs. Furthermore, the diverse learning contexts—from environmental education in PlayPosit to IT courses in Moodle LMS—illustrate the adaptability of these technologies across subjects.

Personalization and real-time feedback emerge as core features in these tools. GIFT employs meta-adaptation for immediate adjustments to learning paths, while SRL-RuAS provides diagnostic reports and scaffolding to support cognitive skill development. These features underscore the shared objective of tailoring content to individual learners while continuously responding to their evolving needs.

Cognitive diversity among students has been another key area of focus in adaptive learning research. The paper "Development of an Adaptive Learning System with Multiple Perspectives Based on Students' Learning Styles and Cognitive Styles" highlights the importance of considering students' cognitive styles in developing effective adaptive systems [30]. The study suggests that personalized learning platforms must account for individual differences in information processing, preferences, and learning strategies to maximize their impact. These findings are crucial to our study, as they underscore the need to adapt learning materials not only based on students' current knowledge but also on their cognitive preferences, a principle we apply in the development of our adaptive mathematics platform.

Additionally, the study "An Adaptive E-learning System for Enhancing Learning Performance: Based on Dynamic Scaffolding Theory" provides a comparative analysis of personalized adaptive learning versus static learning environments, finding that adaptive learning environments are more effective in enhancing students' problem-solving skills and overall academic performance [31]. This insight aligns with our objective of fostering deeper mathematical understanding through personalized scaffolding techniques, tailored to each student's evolving needs.

Furthermore, "The Contribution of Learner Characteristics in the Development of Computer-based Adaptive Learning Environments" proposes a framework that integrates cognitive and learning style characteristics into adaptive learning systems [32]. This study emphasizes the importance of developing systems that adapt not only to what students know but also to how they learn best. By integrating such insights, our platform aims to optimize mathematics learning by aligning educational content with students' individual cognitive profiles, promoting both engagement and retention of complex mathematical concepts.

In Kazakhstan, the adoption of personalized adaptive learning systems is gradually expanding, with several local studies contributing to this growing body of research.

For example, Nadezhda Zhiyenbayeva's study "Personalized Computer Support of Performance Rates and Education Process in High School: A Case Study of Engineering Students" explores how adaptive learning can improve student performance in engineering disciplines [33]. This study demonstrates the effectiveness of personalized learning in helping students, master complex material, reinforcing the global findings on the benefits of tailored educational approaches. Similarly, Zhanat Seitakhmetova's work on the transition to personalized learning in Kazakh primary schools shows how adaptive software can be effectively used to enhance students' mathematics education [34].

Other Kazakh scholars, such as Alma Abylkassymova and Ulzhalgas Yesnazarova, have also explored the role of adaptive learning in mathematics education. Abylkassymova's study on financial literacy formation methods demonstrates how modern technologies, including adaptive platforms, can personalize mathematics learning for university students [35]. Meanwhile, Nurpeisova's research focuses on developing adaptive software for future mathematics teachers, emphasizing the importance of incorporating adaptive learning into teacher education programs [36]. These studies underscore the relevance of adaptive learning in Kazakhstan's educational landscape and align with our study on the application of personalized adaptive learning in mathematics education.

Overall, the growing body of literature on personalized adaptive learning demonstrates its effectiveness across various educational contexts, from primary education to higher education, and across multiple disciplines. By integrating insights from both international and Kazakh studies, our study builds on these findings to explore the effectiveness of adaptive learning systems in improving student outcomes in mathematics at the college level. The next section will outline our methodology for evaluating the impact of a personalized adaptive learning platform in this context.

3 METHODOLOGY

This section outlines the methodology used to assess the effectiveness of the Math Mentor platform in improving students' academic performance and engagement in mathematics. The study involved both a research group, using the personalized adaptive platform, and a control group, following a traditional learning approach. The process included the development of the platform, the experimental design, data collection methods, and analysis techniques.

3.1 Math Mentor platform overview

The Math Mentor platform was designed to offer personalized adaptive learning by automatically adjusting the difficulty of tasks based on individual student performance. The platform includes tools to track student progress, analyze learning data, and provide feedback on learning outcomes. The course "Mathematics" used in this study can be integrated into various educational curricula, whether compulsory or elective, depending on the institution and grade level. The adaptive nature of the platform allowed for individualized learning paths, utilizing different teaching technologies and methods to cater to students' unique needs.

The platform's architecture consists of several levels, beginning with an assessment of the students' prior knowledge. Based on the results, students are assigned tasks that match their performance level. As students master specific skills, they progress to more complex tasks, allowing them to learn at their own pace. This ensures that both struggling and advanced learners are appropriately challenged and supported throughout the course.

Key functionalities of the Math Mentor platform:

1. Progress tracking and reporting: The platform includes a detailed progress dashboard for both students and teachers. Students can view their completed tasks, scores, and areas requiring improvement. Teachers, on the other hand, have access to class-wide performance analytics, enabling them to identify trends and provide targeted support where needed.
2. Adaptive learning paths: Through initial diagnostic testing and continuous performance evaluation, the platform dynamically adjusts the tasks and learning materials. For instance, if a student demonstrates difficulty in algebraic equations, the system offers additional exercises and explanatory resources before advancing them to more complex topics.
3. Immediate feedback mechanism: Each completed task is accompanied by real-time feedback, providing students with insights into their mistakes and guidance for improvement. This feature helps reinforce correct problem-solving strategies and fosters a deeper understanding of mathematical concepts.
4. Interactive and gamified exercises: To maintain engagement, the platform integrates gamified elements into its exercises. These include timed quizzes, achievement badges, and interactive problem-solving tasks, making learning more enjoyable and motivational.
5. Teacher tools and customization: Teachers can tailor assignments and tasks based on their class's needs. The platform allows instructors to add custom problems, set deadlines, and monitor individual and group progress in real time.

In general, the main aspects of personalized adaptive mathematics learning, from addressing individual needs to incorporating varied technologies and teaching methods, as well as testing, evaluation, motivation, and support, are illustrated in Figure 1.

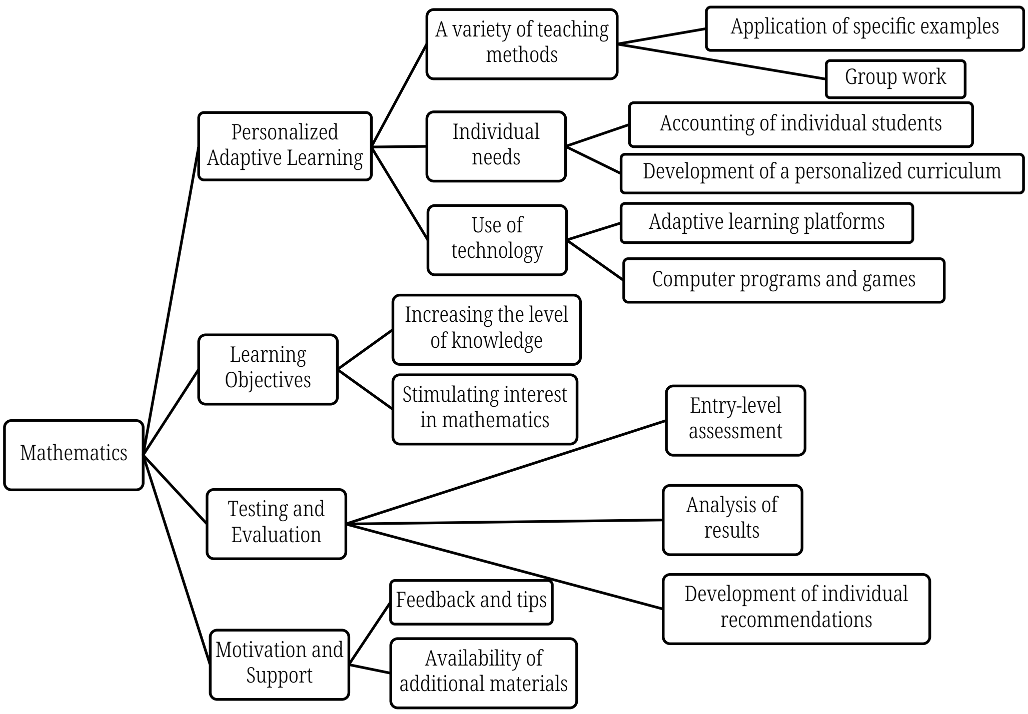

Fig. 1. The concept of personalized adaptive learning in mathematics

To assess the effectiveness of the platform, the learning outcomes of students from the Aktobe Higher Polytechnic College who used the personalized adaptive approach were compared with those following the traditional approach to teaching mathematics. The experiment involved both a control group, which followed traditional learning methods, and a research group, which utilized the Math Mentor platform. The students, all 1st-year students of the Faculty of Software, encountered a wide range of math problems, from basic arithmetic to more advanced topics such as algebra, geometry, trigonometry, and differential calculus.

The Math Mentor platform was designed by a team of specialists in mathematics and programming, ensuring that it adapted to the user's level of knowledge and individual needs. Students practiced solving problems of varying complexity, progressing from basic exercises to more challenging tasks that required a solid understanding of mathematical methods and concepts.

This study was conducted to evaluate the benefits of personalized adaptive learning in a college setting. The popularity of personalized adaptive tools, such as the Khan Academy platform, has been largely due to their ability to allow students to learn at their own pace, addressing individual weaknesses and strengths.

There are several notable software products used in education for personalized adaptive learning in mathematics, including Khan Academy, Adaptive Tech Edu MIT, the adaptive learning program at Harvard University, Sheridan Customized Adaptive Learning, DreamBox Learning, IXL, and Prodigy. These tools are widely recognized for their accessibility and popularity across educational institutions globally. Table 3 provides an analysis of the world's leading colleges that implement personalized adaptive technologies.

Table 3. Leading colleges using personalized adaptive technologies

Name of College	Name of Program	Program Description
Massachusetts Institute of Technology (MIT)	Adaptive Tech Edu MIT	Program based on student learning progress and behavior to determine the most effective learning method.
Harvard University	Adaptive Learning Program	Familiarizes students with strategies for time management, note-taking, test preparation, and critical thinking.
Sheridan College (Canada)	Sheridan Customized Adaptive Learning	Provides students with a learning environment tailored to their unique needs and abilities.
University of Colorado, University of Virginia, University of Texas at Austin, University of Washington, University of California, Berkeley	Dream Box Learning	Analyzes students' knowledge and offers material suited to their level.
University of Maryland, University of Houston, University of Illinois, Stanford University, New York University, University of Michigan	IXL	Provides adaptive learning by offering tasks based on the student's knowledge level and skill improvement.
Stanford University, York University, University of California Berkeley, University of Pennsylvania	Prodigy	A natural language learning and processing platform using machine learning and AI to enhance human-computer interaction.

To facilitate student learning, the authors also developed a personalized adaptive web application. The main objective of the Math Mentor platform is to provide students with access to mathematical materials, solutions, and interactive learning tools. To use the platform, students need to "Register" or "Create an account" (see Figure 2).

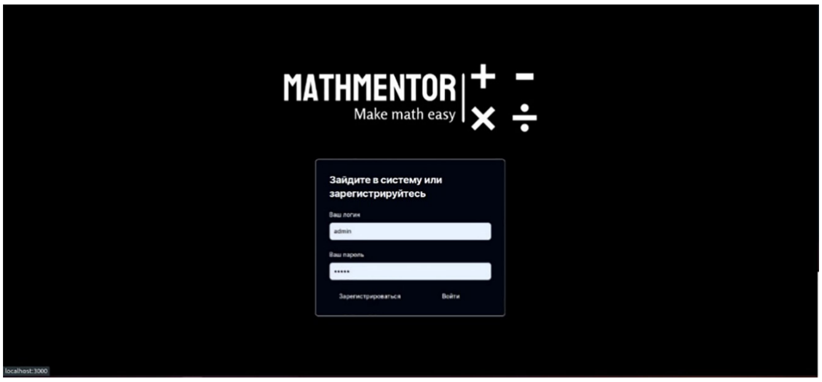

Fig. 2. Application login page

The platform employs various modern technologies, including:

1. **Django Rest Framework:** A Python-based framework used to create the backend of the platform, providing data management and interaction with the frontend.
2. **Python:** The primary language used for backend functionality and integration modules.
3. **Docker:** Automates the deployment and management of applications in containers, streamlining the platform's setup.
4. **React, JavaScript, HTML, CSS:** These tools are used for frontend development, facilitating user interface creation and interaction with the backend.
5. **ArcPy in Python:** A module for geographic data processing, used to integrate geographical capabilities into the Math Mentor platform.

The platform's architecture enables the creation of personalized learning paths tailored to each student's level of knowledge, interests, and needs. Figure 3 demonstrates how the tasks are structured and organized within the personalized adaptive course.

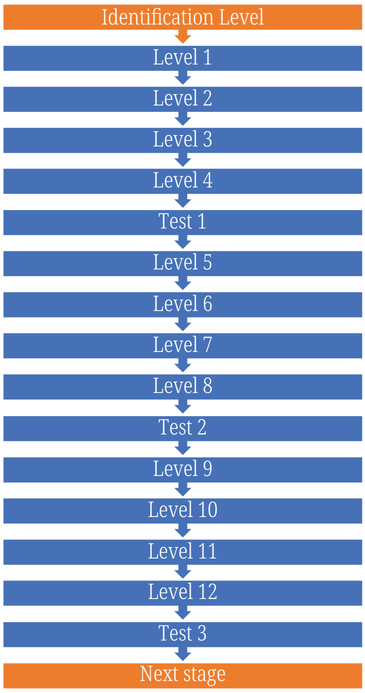

Fig. 3. Personalized adaptive course level and task architecture

To proceed to the next level of training, students must meet certain criteria or achieve specific success rates. Some steps to advance include:

1. Mastering the basic concepts and skills at the current level by completing exercises and passing tests.
2. Reviewing progress and addressing weaknesses, possibly requiring extra time for challenging topics.
3. Understanding the requirements for advancing, which may involve achieving high test scores or completing special tasks.
4. Seeking help when needed, whether from a tutor, teacher, or peer.
5. Planning time efficiently and setting incremental goals to ensure steady progress.
6. Consistent practice, as mathematics requires repeated application and refinement of skills.

In conclusion, the Math Mentor platform significantly promotes effective learning by providing personalized, adaptive paths for students. By continuously assessing and adapting to students' needs, the platform offers feedback, motivation, and support to help students overcome challenges and achieve success in learning mathematics.

3.2 Experimental setup

The study was conducted at Aktobe Higher Polytechnic College with a total of 118 1st-year students from the Faculty of Software. The students were randomly divided into two groups:

- Control group (n = 59): These students followed a traditional learning approach, with all learners receiving the same assignments and materials.
- Research group (n = 59): These students used the Math Mentor platform, where learning was personalized based on their skill level.

Both groups studied the same mathematics curriculum, but the research group's experience was mediated by the adaptive platform. The curriculum covered a range of topics, from basic mathematical operations to advanced subjects such as algebra and calculus.

3.3 Data collection and evaluation

To measure the effectiveness of the Math Mentor platform, both pre-tests and post-tests were administered to the control and research groups. These tests assessed students' knowledge of mathematical concepts before and after the intervention. The pre-test provided baseline data on students' prior knowledge, while the post-test helped evaluate their progress.

Additionally, the platform tracked several key metrics:

- Task completion rates: The platform logged when and how students completed tasks, allowing for the assessment of engagement and task completion efficiency.
- Time spent on tasks: The platform tracked how long students spent on each task, providing insights into their familiarity with the material and learning efficiency over time.

- Final exam results: Both groups completed the same final exam, and their results were compared to assess the overall impact of the platform on their academic performance.

3.4 Student feedback

At the end of the semester, students were asked to complete a questionnaire that gathered feedback on their experience using the Math Mentor platform. The questionnaire evaluated the platform's usability, perceived effectiveness, and areas for improvement. This provided valuable qualitative data on student satisfaction and engagement.

The main aspects of the methodology allowed for a clear comparison of learning outcomes between the two groups, using both quantitative performance metrics and qualitative student feedback.

3.5 Data analysis

The data collected from the pre-test, post-test, task completion rates, final exam scores, and student feedback were analyzed to assess the effectiveness of the Math Mentor platform. Statistical analysis was conducted to compare the improvement rates between the control and research groups, while qualitative data from the feedback survey were used to identify areas of strength and potential improvement for the platform.

The following sections present the detailed analysis of the results obtained through this methodology, emphasizing how the Math Mentor platform influenced student learning and engagement in comparison to traditional teaching methods.

4 RESULTS

The implementation of the personalized adaptive course "Math Mentor" was assessed by comparing the performance and engagement of students using the platform with those following a traditional learning approach. This section provides a detailed analysis of the results based on pre-test and post-test scores, task completion rates, engagement data, final exam outcomes, and student feedback on the usability of the platform.

4.1 Comparison of pre-test and post-test results

Both the control and research groups took pre-tests and post-tests to assess their knowledge before and after the intervention. The control group followed a traditional teaching approach, while the research group used the Math Mentor platform, which adjusted the task difficulty according to each student's performance. The results are shown in Table 4. The research group demonstrated a greater improvement (22.8%) in their post-test scores compared to the control group (14.2%), indicating the effectiveness of personalized adaptive learning in enhancing students' understanding of mathematical concepts.

Table 4. Comparison of pre- and post-test scores

Group	Pre-Test Average	Post-Test Average	Improvement
Control Group	52.7%	66.9%	14.2%
Research Group	48.7%	71.5%	22.8%

To provide further insights into the effectiveness of the Math Mentor platform, we analyzed the improvement in specific mathematical skills. The following table presents the pre-test and post-test scores along with improvement percentages for key topics such as algebra, geometry, and calculus. As shown in Table 5, the improvements were consistent across mathematical skills, with geometry showing the highest improvement (23.0%), followed by algebra (22.8%) and calculus (22.5%). These results highlight the platform's capacity to address diverse mathematical competencies effectively, supporting personalized adaptive learning as a robust approach to enhancing student outcomes.

Table 5. Comparison of pre- and post-test scores

Mathematical Skill	Pre-Test Avg. Score (%)	Post-Test Avg. Score (%)	Improvement (%)
Algebra	48.5	71.3	22.8
Geometry	48.0	71.0	23.0
Calculus	49.6	72.1	22.5
Average	48.7	71.5	22.8

4.2 Task completion and engagement

The Math Mentor platform tracked students' progress, including the time spent on tasks and task completion rates. This data helped monitor student engagement and their ability to handle increasingly complex mathematical tasks over time.

Figure 4 shows the average time spent on tasks by students in the research group. The graph indicates a noticeable reduction in task completion time as students became more familiar with the platform and more efficient in solving problems.

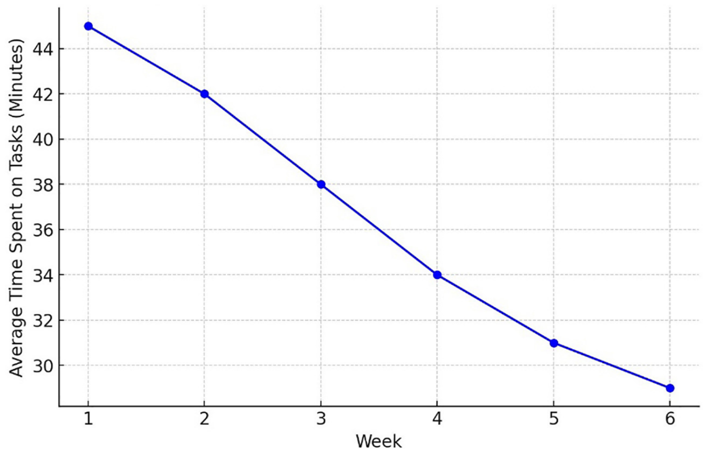

Fig. 4. Average time spent on tasks in the research group

This suggests that students adapted to the personalized learning platform and improved their problem-solving efficiency as they progressed through the course.

4.3 Learning outcomes

The learning outcomes highlight the significant impact of the personalized adaptive learning platform on students' academic performance. Table 6 below provides a clear comparison between the exam results of the research group, which used the Math Mentor platform, and the control group, which followed traditional teaching methods.

Table 6. Learning outcomes

Grade Range	Research Group – Number of Students	Control Group – Number of Students
100 ÷ 80	7	3
80 ÷ 65	20	15
65 ÷ 50	30	25
< 50	2	16

As shown in Table 6, students in the research group achieved significantly better results compared to the control group. The number of students in the research group who scored 80 or above (27 students) was more than double that of the control group (18 students), underscoring the effectiveness of the personalized adaptive learning approach. Moreover, only 2 students in the research group scored below 50, compared to 16 in the control group, indicating the platform's success in helping students overcome academic challenges.

These results demonstrate that the Math Mentor platform significantly fostered academic success, particularly among students who struggled in traditional teaching environments. The findings reinforce the value of personalized adaptive learning in addressing individual learning needs and improving overall performance.

4.4 Student feedback on platform usability and effectiveness

At the end of the semester, a questionnaire was administered to gather student feedback regarding their experience with the Math Mentor platform. The responses were largely positive, indicating general satisfaction with the platform's usability and effectiveness.

57% of students rated the quality of the Math Mentor platform as "good," while 28% rated it as "excellent." This breakdown of ratings is visually displayed in Figure 5, highlighting the majority approval of the platform's overall quality. However, despite this positive feedback, students raised concerns regarding the accessibility of results, with 25% rating this feature as either "satisfactory" or "unsatisfactory." This points to a potential area for improvement in the platform's interface related to accessing academic results.

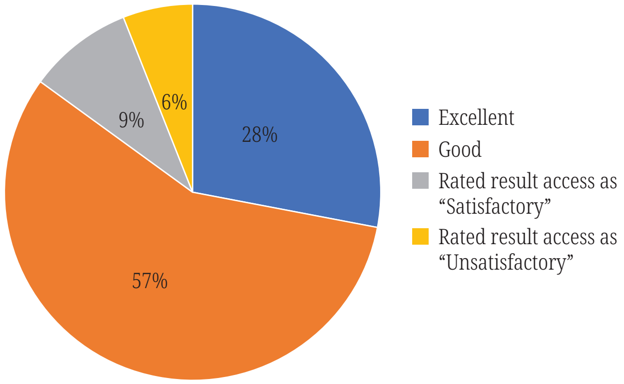

Fig. 5. Student preferences for network communication in the Math Mentor platform

Another area of concern was network communication within the platform. Some students preferred face-to-face consultations over online interactions, which is illustrated in Figure 6, where 40% of students preferred face-to-face consultations, and others opted for alternative communication methods.

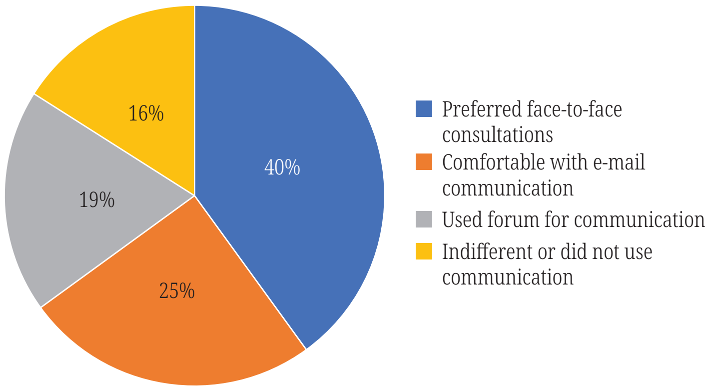

Fig. 6. Breakdown of student ratings for the quality of the Math Mentor platform

When asked about the overall effectiveness of the platform for personalized adaptive learning, 74% of students found the platform effective. On the other hand, 12% of the students preferred traditional education methods, while 14% were undecided or unable to provide a definitive answer, as shown in Figure 7.

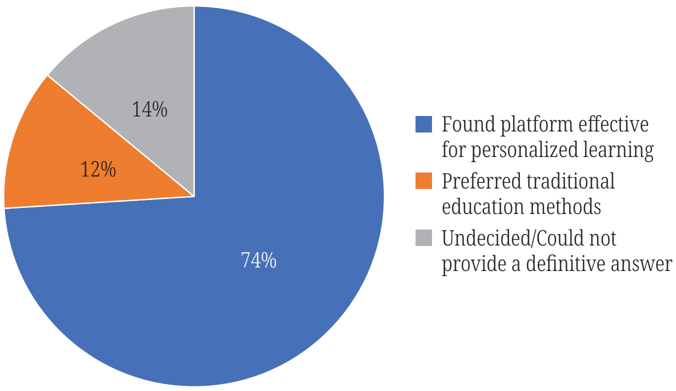

Fig. 7. Student feedback on the effectiveness of the Math Mentor platform for personalized adaptive learning

These figures provide clear insights into student preferences, satisfaction, and areas needing improvement within the Math Mentor platform.

4.5 Elimination of disparities in mathematics performance

The results demonstrated that the Math Mentor platform was particularly effective in eliminating disparities in performance between students who had weaker prior knowledge of mathematics and those who were stronger in other academic disciplines. By adjusting task difficulty based on individual performance, the platform ensured that all students could progress at their own pace and improve their understanding.

4.6 Engagement and independent work skills

The platform also fostered the development of independent work skills, including time management and goal-setting. By providing personalized learning paths and real-time feedback, students were encouraged to plan their study schedules, set incremental goals, and monitor their progress independently. While some students struggled initially due to a lack of independent learning skills, over time they became more efficient, as shown by their improved task completion rates.

In conclusion, the Math Mentor platform significantly improved students' academic performance and engagement in the subject of mathematics. The platform's ability to personalize learning pathways allowed students to achieve better results, develop independent learning skills, and close gaps in their mathematical knowledge. The study demonstrates the potential of personalized adaptive learning to enhance educational outcomes in diverse learning environments.

5 DISCUSSION

The results of this study provide strong evidence supporting the effectiveness of personalized adaptive learning in improving students' mathematical performance and engagement. The Math Mentor platform allowed students in the research group to achieve higher post-test scores and final exam results compared to their peers in the control group, who followed traditional learning methods. This aligns with existing literature that emphasizes the advantages of adaptive learning systems in providing individualized learning paths that cater to students' unique strengths and weaknesses.

The platform's ability to adapt task difficulty based on each student's performance was particularly effective in reducing the time spent on tasks as students progressed through the course. Beyond improving problem-solving efficiency, the platform played a key role in fostering independent learning skills such as time management and goal-setting. These skills were cultivated through personalized learning paths that required students to set achievable goals, manage their study schedules effectively, and monitor their progress in real-time. Such competencies are critical for long-term academic success and highlight the broader educational potential of adaptive learning systems.

Moreover, student feedback reflected a largely positive reception of the platform, with most students appreciating its adaptability and real-time feedback features.

However, concerns were raised about the platform's result accessibility and online communication features, indicating areas that need improvement. The fact that some students preferred face-to-face consultations over the platform's communication tools highlights the need to balance technological interventions with more traditional, interpersonal support in educational settings.

Overall, the study demonstrates that personalized adaptive learning can be a valuable tool for improving educational outcomes, particularly in mathematics, where many students struggle with abstract concepts. However, as with any technological intervention, it is essential to ensure that the platform is user-friendly and that its features are well-integrated into the broader educational framework.

6 LIMITATIONS

Despite the promising results, several limitations need to be acknowledged:

1. Sample size and generalizability: The study involved a relatively small sample size of 118 students from a single institution, which may limit the generalizability of the findings. Future studies should consider larger and more diverse samples to validate the results across different educational contexts and student populations.
2. Short-term study: The duration of the study was limited to one semester, which may not capture the long-term benefits or challenges of using personalized adaptive learning platforms. It is unclear whether the improvements in student performance would be sustained over a more extended period.
3. Technical and usability challenges: While the platform was generally well-received, some technical challenges, such as difficulty in accessing results and issues with network communication, were reported by students. These challenges may have impacted their learning experience and should be addressed in future iterations of the platform.
4. Teacher involvement: The study did not explore the role of teachers in using the Math Mentor platform alongside traditional instruction. Teacher involvement could play a critical role in guiding students' use of the platform and should be considered in future studies.

7 CONCLUSIONS AND FUTURE RESEARCH

This study has demonstrated the potential of personalized adaptive learning platforms, specifically the Math Mentor platform, to enhance mathematics education at the college level. By providing individualized learning paths and real-time feedback, the platform significantly improved students' academic performance, engagement, and problem-solving skills compared to traditional teaching methods.

The results underscore the importance of adapting educational technologies to meet the diverse needs of students. Personalized adaptive learning systems such as Math Mentor can offer tailored support to both high-performing and struggling students, ensuring that each student receives the guidance and challenges necessary for their academic growth.

However, for the full potential of such platforms to be realized, it is essential to address technical usability issues, ensure that students can easily access their progress reports, and maintain a balance between online learning and interpersonal support from teachers. The study highlights the need for further research into the long-term impact of adaptive learning technologies and their integration into broader educational systems.

The findings of this study open several avenues for future research:

1. Long-term impact: Future studies should investigate the long-term effects of personalized adaptive learning platforms. Does the improvement in student performance continue over multiple semesters or academic years? Longitudinal studies would provide valuable insights into the sustained benefits of adaptive learning technologies.
2. Teacher's role in adaptive learning: While this study focused on student outcomes, future research should explore the role of teachers in implementing and optimizing adaptive learning platforms. Understanding how teachers can use data from the platform to guide instruction could enhance the effectiveness of these tools.
3. Integration with other subjects: While this study focused on mathematics, the platform's adaptability could be extended to other subjects such as science, language arts, or social studies. Further research could assess the effectiveness of personalized adaptive learning in different disciplines and across various educational levels.
4. Addressing usability issues: Future research should investigate how to improve the usability of adaptive learning platforms, particularly in terms of accessing results and facilitating effective communication. Gathering more detailed feedback on student and teacher experiences with the platform could lead to important design improvements.
5. Inclusive learning: Research should explore how personalized adaptive learning can be used to support students with learning disabilities or those from diverse socio-economic backgrounds. Adaptive platforms could play a crucial role in closing achievement gaps and ensuring that all students receive the support they need to succeed.

In summary, while this study highlights the benefits of personalized adaptive learning in mathematics education, there is a clear need for further exploration into its long-term effectiveness, broader application, and potential improvements. With continued development and research, adaptive learning platforms have the potential to transform education and improve learning outcomes for students in various contexts.

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