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PAPER

Design and Evaluation of an Intelligent Adaptive Learning System Using Generative Artificial Intelligence

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ABSTRACT

The use of adaptive learning systems with artificial intelligence (AI) in education has changed how educators teach by providing a customized learner experience that matches the particular characteristics of each learner, thus increasing both learner engagement and learning outcomes. This article provides a description of the design, development, and evaluation of a generative AI-based interactive mobile learning system designed to increase learner engagement, increase the ability for the learner to acquire knowledge, and provide improved access to educational resources. By using a mobile-based learning platform, learners have access to real-time tutoring, generated, determined feedback, generated instructional materials, and interactive learning experiences, 24 hours a day, seven days a week. The system architecture consists of user profiling, a learning analytics engine, and a content generation process for creating dynamic course materials using GenAI and providing feedback and making recommendations. These four components of the system work together to create personalized learning paths for individual learners and to enhance the ongoing learning processes of all learners. A thorough assessment of the proposed approach was conducted by utilizing multiple methods with students from a wide variety of educational backgrounds in order to measure the effectiveness of the AI-based adaptive learning system. Students' performance (effectiveness) was measured using both quantitative metrics and qualitative feedback, including measures of learning success (i.e., test scores), levels of engagement (i.e., how often students engage with the material), completion rate (number of tasks completed vs. total number of tasks assigned), and satisfaction (whether learners felt satisfied with their adaptive learning experience). Based on the results of all evaluations performed, it has been found that AI-based adaptive learning systems provide greater motivation, more successfully comprehend course content, and a higher level of academic performance compared to the use of traditional mobile learning apps.

KEYWORDS

adaptive learning, artificial intelligence (AI), personalized learning, mobile learning system

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1 INTRODUCTION

Many people in society have noticed that education has changed a lot recently due to advances in technology. When this first started happening [1], schools were very much based on the same teaching style for everyone and had set curriculums; however, now there is a greater demand for more individualized and adaptive educational experiences. Digital technologies and increased access to the internet across the world are creating ideas for new ways of learning, one of these being through the use of adaptive learning systems [2]. Adaptive learning systems are designed to improve student outcomes within the educational system by providing adaptive learning experiences that are specific to each student.

The idea of personalized education is a very hot topic of innovation in the field of education. There are many possibilities for creating custom-tailored learning materials [3], specifically through generative artificial intelligence (AI) technology that can produce millions of different resources for each individual student based on their specific needs and interests. The use of generative AI allows educators to spend the majority of their time working with students in meaningful ways and employing complex teaching strategies [4], rather than completing repetitive tasks (such as grading student work or developing curricular plans). In addition to enhancing creativity and providing students with many unique opportunities to explore concepts and ideas, generative AI will also improve student collaboration and problem-solving in all subject areas [5].

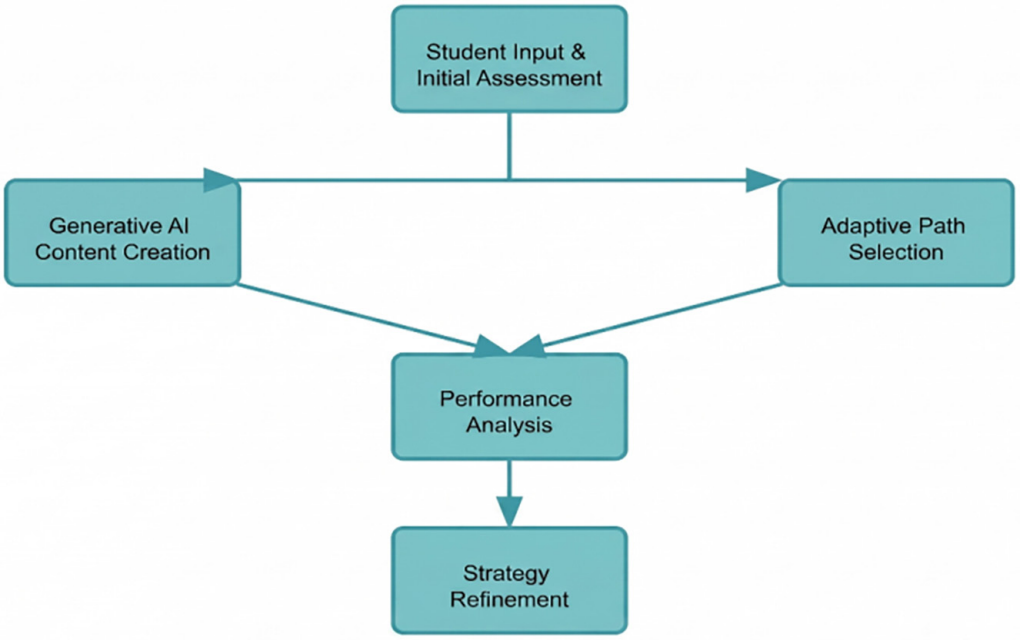

Fig. 1. Workflow of adaptive learning

In this rapidly evolving world, the rise of generative AI (artificial intelligence) has created opportunities for implementing customized teaching methodologies that change how we think about education through creating and changing instructional resources on an as-needed basis [6]. In recent research, generative AI systems have demonstrated their ability to create tailored content for (among other uses) delivering feedback to individual learners, developing content that changes as learners

progress through course material, and facilitating the creation of more engaging, inclusive, and exciting experiences for learners [7].

Traditional adaptive learning systems do not meet the diverse needs of students with many different disabilities [8]. Current systems do not provide sufficient support for students with sensory impairments, cognitive impairments, and/or attention issues. This study seeks to determine how generative AI can close these gaps by providing more personalized, accessible, and responsive forms of education assistance [9].

1.1 Research questions

This study seeks to provide critical evaluation on three areas [10], answering the following questions:

RQ1: How can generative AI-driven adaptive learning systems be used to effectively individualize learning materials based on the learner's characteristics and previous engagements?
RQ2: Does using an adaptive learning system improve a learner's level of engagement versus using a traditional e-learning system?
RQ3: What effect does using a generative AI-driven adaptive learning system have on a learner's academic performance and retention of knowledge?
RQ4: How accurate and effective are the personalized recommendations provided by the generative AI-powered adaptive learning system for advancing the learner?
RQ5: How do learners perceive usability, satisfaction, and trust in a generative AI-based adaptive learning environment?

The main contributions of this study are the following:

This study explored how AI-enabled learning platforms can engage students as well as how efficiently those same students were learning after being taught through AI-enabled learning platforms as opposed to 'traditional' teaching methods.

This study has compared several popular AI-enabled learning platforms and indicated their various adaptive learning methodologies and how they might be used to improve educational accessibility.

The research showed that compared to traditional teaching methods, adaptive learning provides an enhanced improvement in student knowledge retention and skills-related learning benefits (learning outcomes).

2 RELATED WORKS

[11] Investigates how the use of various AI-driven adaptive learning systems improves educational performance and levels of participation for disabled students. It highlights the results of providing customized educational supports that meet the students' accessibility requirements in cognitive growth as well as educational performance. It has utilized interaction behavior data collected through users' training, work demands on the users while they were in training, and the users' cognition to describe the processes by which these systems perform more effectively for users. AI-driven adaptive learning systems produce improved levels of participation, comprehension, and recall for students with learning disabilities, thereby lessening the

academic achievement gap between them and their peers. The study affirms the need for, and suggests certain aspects of, inclusive AI design. Future research could include ethical AI governance, multidisciplinary collaboration, and user-driven design to address how the adaptive learning system can meet the needs of disabled students. There is tremendous opportunity for AI-driven adaptive learning systems to develop more inclusive and individualized educational experiences for students with disabilities.

[7] Examines the effectiveness of adaptive learning systems driven by artificial intelligence in improving the quality of education and equity among various populations and environments through a mixed-methods design. Data were collected through quantitative means, including pre- and post-assessment tests, surveys, and system analytics, as well as qualitative means through interviews with participants who included 300 students and 50 educators from primary through postsecondary levels. The results of this study revealed that there was a significant increase in student achievement from the pre-assessment test (68.4 average) to the post-assessment test (82.7 average). Further, the use of AI-driven tools such as Smart Sparrow and IBM Watson Education demonstrated increased course completion rates and higher levels of student engagement. In addition, comparative analysis revealed that adaptive systems were more effective than traditional approaches for improving student achievement. Therefore, the findings of this study indicate that AI-driven adaptive learning systems have the potential to improve the quality and equity of education.

[12] Presents a new approach to education that provides personalized learning through AI-based Adaptive Learning Systems (ALS) will transform how we deliver higher education today. Traditional education was built on a standardized model, and we will utilize AI in an ALS to leverage its ability to change the way curricula are created and delivered. The proposed ALS will utilize machine learning algorithms to dynamically customize the learning experience for each student. As part of this model, there will be an aspect of data collection, preprocessing, and algorithm selection. The implementation model will provide a practical reference for how to implement the ALS, including the types of technology required, the infrastructure necessary to support an ALS system, and the challenges that may arise. Experimental results indicate significant improvements in learning outcomes and engagement resulting from this new model. This document calls for the widespread use of AI-driven adaptive learning and provides a pathway toward transforming how higher education is delivered by providing a dynamic, customized, and unique learning experience for all students regardless of their backgrounds or skills.

3 PROPOSED METHODOLOGY

The methodology outlined provides a strong foundation for evaluating adaptive learning systems that are driven by AI using both quantitative and qualitative methods. The research has both experimental and observational elements to provide a comprehensive evaluation of how effective adaptive systems are. Future research could expand on this study by including institutions from different geographical locations to better understand how adaptive systems operate in different types of educational environments, as given in Figure 2. Additionally, the use of real-time monitoring technologies could improve the accuracy of the data collected and provide additional information about student engagement in the adaptive systems being evaluated. Making these improvements will help to support the conclusions of this study and provide additional opportunities for scalable and equitable uses of AI in education.

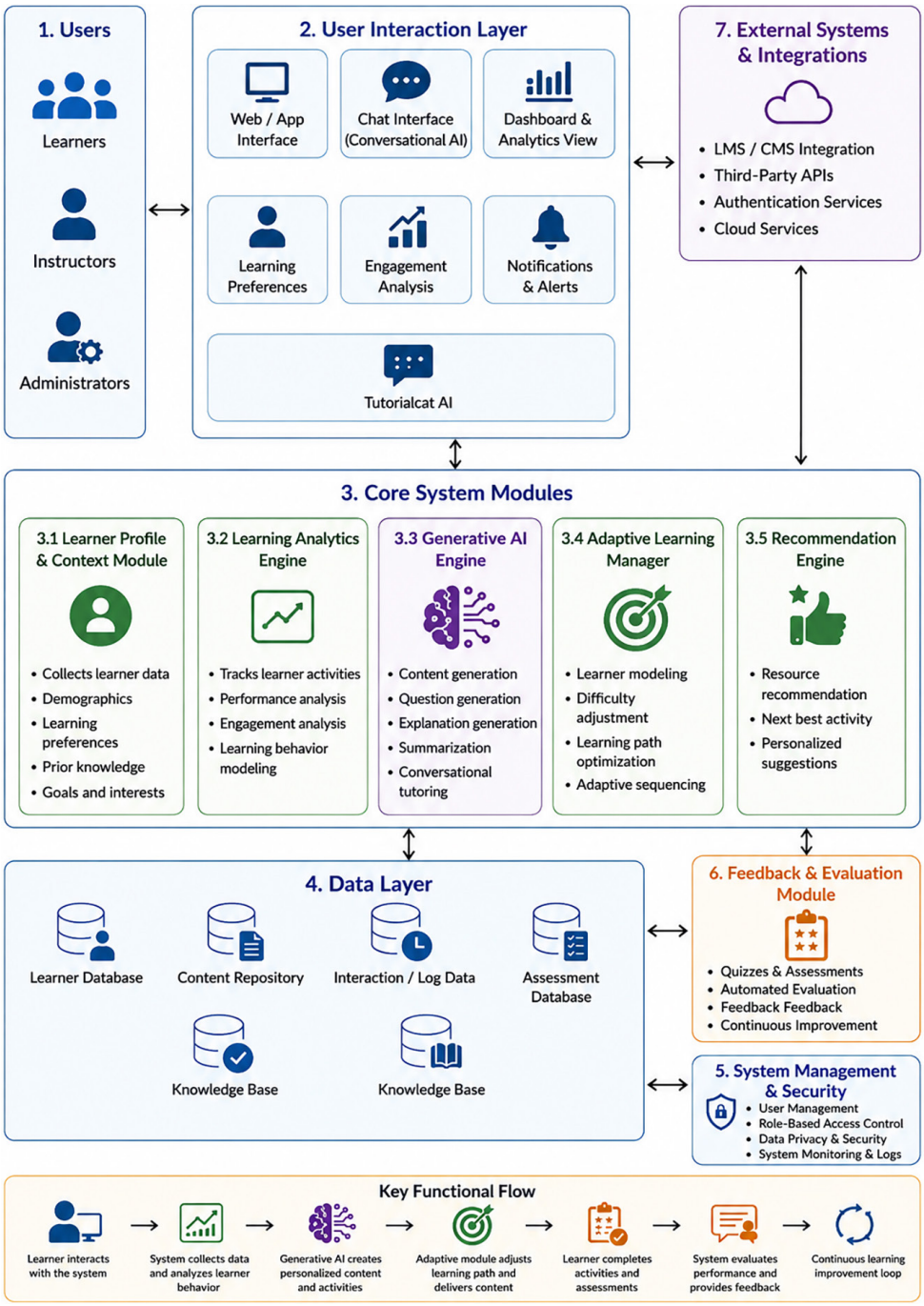

Fig. 2. Overall working process of the proposed model

3.1 Data collection

In this study, data collection consisted of utilizing surveys and questionnaires distributed to both educators and students. Surveys were utilized to gain insight into participants' experience with the system being evaluated. Surveys collected information regarding users' perceptions of the system's effectiveness and usability, and how it affected their motivation and engagement beyond simply using the system. The data collected through surveys and questionnaires provided a first-hand experience from users of the system being evaluated, which assisted in developing

an understanding of how the system was viewed by users within an educational setting [13].

To assess student performance using post-assessments, the researchers tracked student achievement before students began to use the adaptive learning system (pre-assessment) to determine each student's initial understanding of the material and after students used the adaptive learning system (post-assessment). Using pre- and post-assessment data, the researchers were able to quantify student improvement as measured by their assessment scores; differences in assessment scores indicated improvement in the learning outcomes of students relying on AI technology. Using post-assessments helped the researchers to objectively evaluate the effectiveness of the adaptive learning system. In addition to using post-assessment data, quantitative data from system logs and analytics collected from the AI-based adaptive learning system provided a broad-based perspective regarding how the adaptive learning system has influenced users' learning experience. These records provide critical information about the amount of interaction that students have with the platform, their engagement with the platform, and their progress toward reaching various learning milestones. Researchers were able to monitor how students used the system through the utilization of logs generated by the adaptive-learning system in order to determine usage patterns for the platform and its various components. These analytics also permit the evaluation of how successfully the system has improved students' levels of engagement and learning outcomes. Collecting both qualitative and quantitative data from a variety of sources, including surveys, questionnaires, post-assessments, interviews, and system logs, will provide a comprehensive overview of how an artificial intelligence-based adaptive learning system has affected educational outcomes in an educational environment. This approach enables an informed understanding of the effectiveness, challenges, and opportunities of using adaptive technologies to enhance the educational experience of students.

3.2 Participants

This research will be conducted using a sample of approximately 120 students in grades 1 to 12 and 50 teachers/educators at all levels of the educational system (primary, secondary, and post-secondary). The researchers will ensure participants represent a cross-section of the population and an equal number of groups by collecting demographic data, including but not limited to geographic area, to determine what effect those variables may have on the research outcome.

3.3 Tools and technologies

The use of multiple AI solutions and adaptive learning technologies to assess their effect on student performance is based on the fact that this AI-supported adaptive learning platform provides users with personalized learning pathways that are matched to each student's characteristics and performance data. This means that students will have access to custom-designed learning paths created specifically for them to improve their learning outcomes [14].

3.4 Data analysis

Investigative analysis will evaluate the influence of AI adaptive learning systems on outcomes in education using both qualitative and quantitative methods.

The quantitative portion of the evaluation uses statistical methods to objectively assess the performance of adaptive learning systems. For example, students' performance scores can be compared before and after using an adaptive learning system with the t-test, which compares the means of two groups. This will indicate whether or not there is a statistically significant change in the student scores that can be attributed to the use of the adaptive learning system. The quantitative analysis provides numerical evidence of changes (from student performance and engagement), therefore allowing for the researcher to measure the effect of the systems on education quantitatively. A comparative analysis will be conducted to evaluate and compare the level of student performance and engagement using adaptive learning systems as it relates to student performance and engagement on traditional learning methods. This analysis will help to provide insight on the relative effectiveness of the adaptive systems, meaning, for example, that if students in the adaptive learning group demonstrate greater success in their post-assessment scores than students in the traditional learning group, then there is evidence to support the advantages of the adaptive systems over the traditional systems. In using quantitative, qualitative, and comparative analyses, the research study will seek to develop a comprehensive understanding of the impact of AI-driven adaptive learning systems on education. Additionally, the mixed-methods design of the research will reveal both the advantages and disadvantages of the use of adaptive learning systems in education, thus providing a complete perspective of how adaptive learning systems may be effective and what challenges may exist when implementing adaptive technology in education.

4 EXPERIMENTAL RESULT

Statistics are used to describe the characteristics of the populations that were sampled, which included data collected from 320 students and 50 educators. The data were analyzed in order to understand the overall impact that AI adaptive learning systems had on participants by summarizing each participant's demographic characteristics in Table 1.

Table 1. Demographic characteristics of participants

Demographic Variable	Category	Frequency	Percentage (%)
Age	10–15 years	72	22.50
	16–20 years	108	33.75
	21–25 years	92	28.75
	Above 25 years	48	15.00
Gender	Male	172	53.75
	Female	148	46.25
Educational Level	Secondary Education	124	38.75
	Undergraduate	136	42.50
	Postgraduate	60	18.75
Subject Area	STEM	142	44.38
	Social Sciences	98	30.62
	Business and Management	46	14.37
	Arts and Humanities	34	10.63

The enerative AI-Powered Adaptive Learning Evaluation involved 320 participants. Participants spanned numerous ages, educational stages, and types of academic study. The majority of the participants were between the ages of 16–20 (33.75%) and 21–25 years old (28.75%). Most of the participants were undergraduate students (42.50%), with the highest representation of participants (44.38%) in STEM fields. The diverse composition of participants was beneficial to an extensive evaluation of the system across various learning environments and levels of education.

The study shows that in Figure 3, the generative AI adaptive learning system can personalize content to fit the individual characteristics of each learner based on their performance level. Additionally, researchers found a general trend where those learners utilizing the adaptive-learning system increased their rates of task completion and level of proficiency from the beginning of the study period to the end of the period of time they've participated in the study. Furthermore, all adaptive-learning mechanisms in the system provided ongoing adjustments made to both the type of content presented to learners and the amount of difficulty associated with each content item and the types of feedback used to provide targeted assistance to each learner by allowing for a continual dynamic manner. Based on this evidence, the proposed adaptive learning system met the initial research questions (RQ1) regarding the effectiveness of personalized adaptive learning for increasing efficiency of learning and flexibility to meet the needs of all learners.

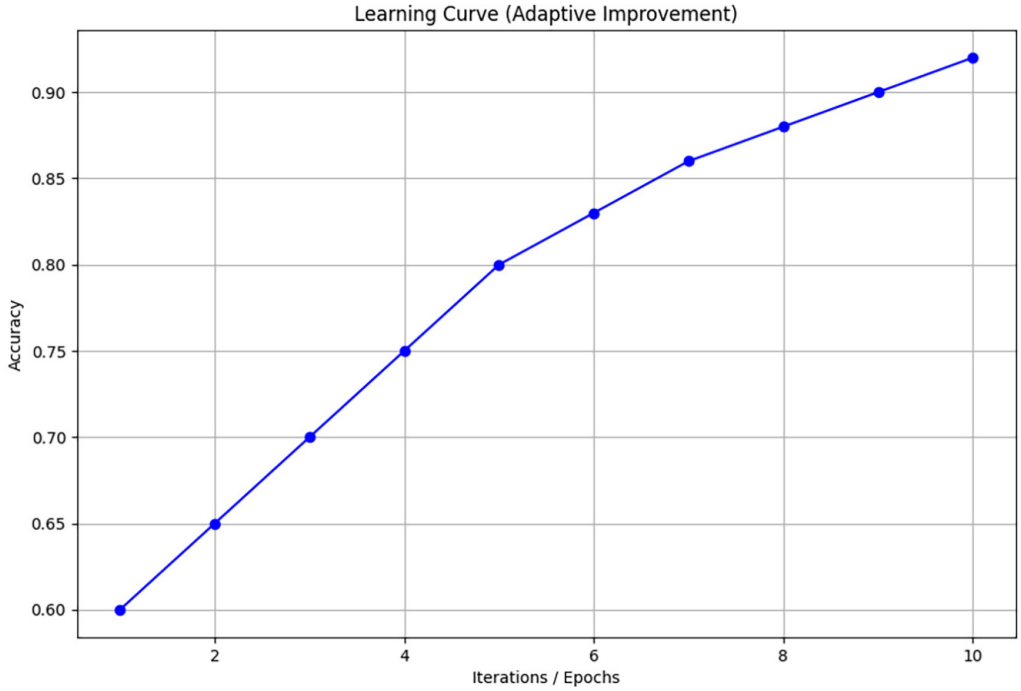

Fig. 3. Adaptive learning effectiveness analysis

In Figure 4, the experimental results illustrate a substantial increase in improving learning outcomes for users of the system. Post-assessment scores of all users consistently outperformed Pre-assessment scores, illustrating successful transfer of knowledge and retention. Use of the AI-created path of the user's learning and knowledge and personalized content for each individual learner results in overall improvement for the user academically. The data clearly supports that adaptive learning supports learners in comprehending subject content and leads to improved educational outcomes when compared to traditional learning methods.

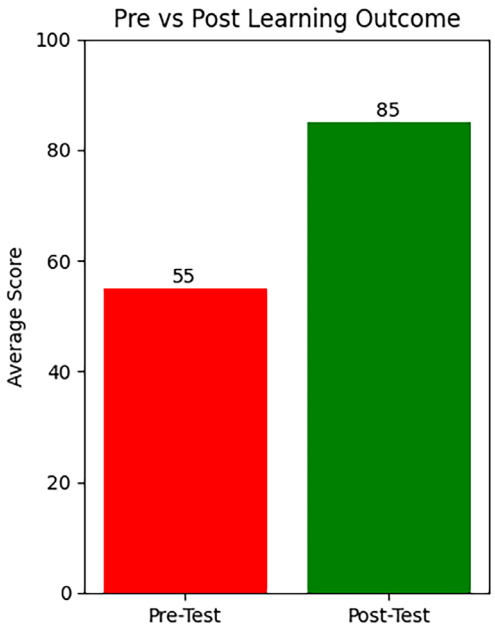

Fig. 4. Assessment of pre vs. post learning outcome

The analysis of learner engagement indicated in Figure 5 demonstrates there was an increase in participation, frequency of interaction, and length of the session when using this new system. The features of live feedback, conversational AI assistance, and personal recommendations encouraged more active learner participation. In addition, the engagement trends indicate that the interactive qualities of generative AI systems helped to maintain learner motivation and reduced learner disengagement. Consequently, these results indicate that adaptive and interactive learning environments can greatly improve learner engagement and satisfaction.

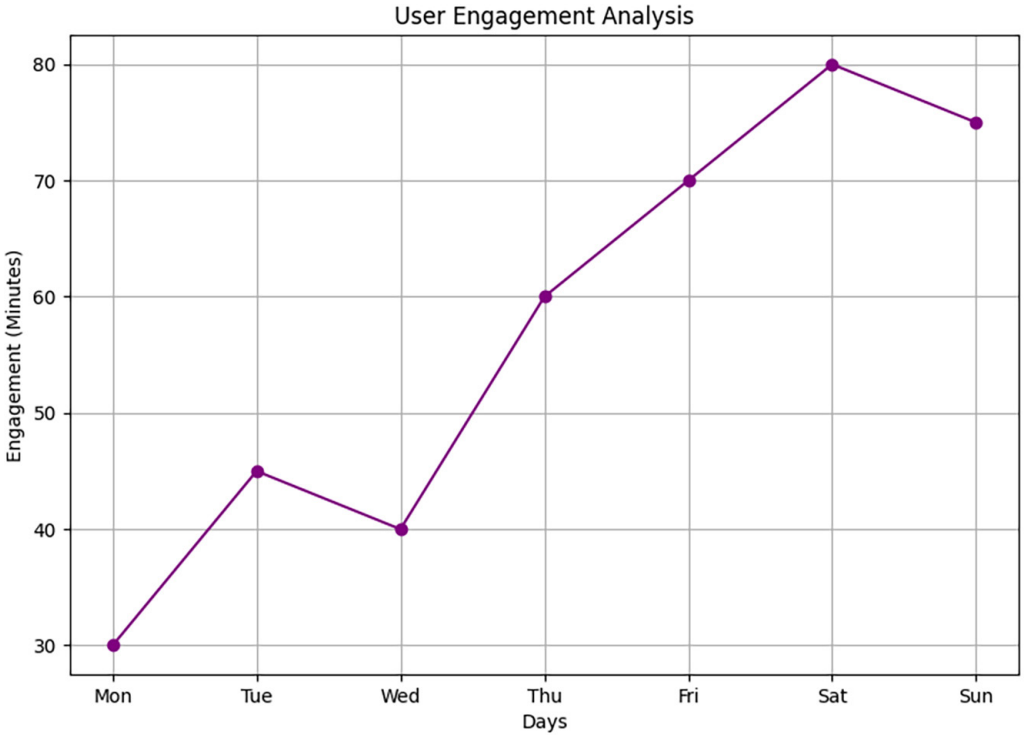

Fig. 5. Analysis of user engagement

Based upon the data presented in Figure 6, it can be concluded that the recommendation engine generated accurate results to present individualized learning resources and activities. The personalized content recommendations provided by the system closely matched each learner's varied interests, baseline knowledge, and desired learning outcomes. As learners progressed through the platform, the recommendation engine's effectiveness at making suitable recommendations increased due to ongoing analysis of user engagement and performance metrics. The outcomes of this study substantiate that generative AI models are capable of providing meaningful, contextualized recommendations that promote an individualized learning experience.

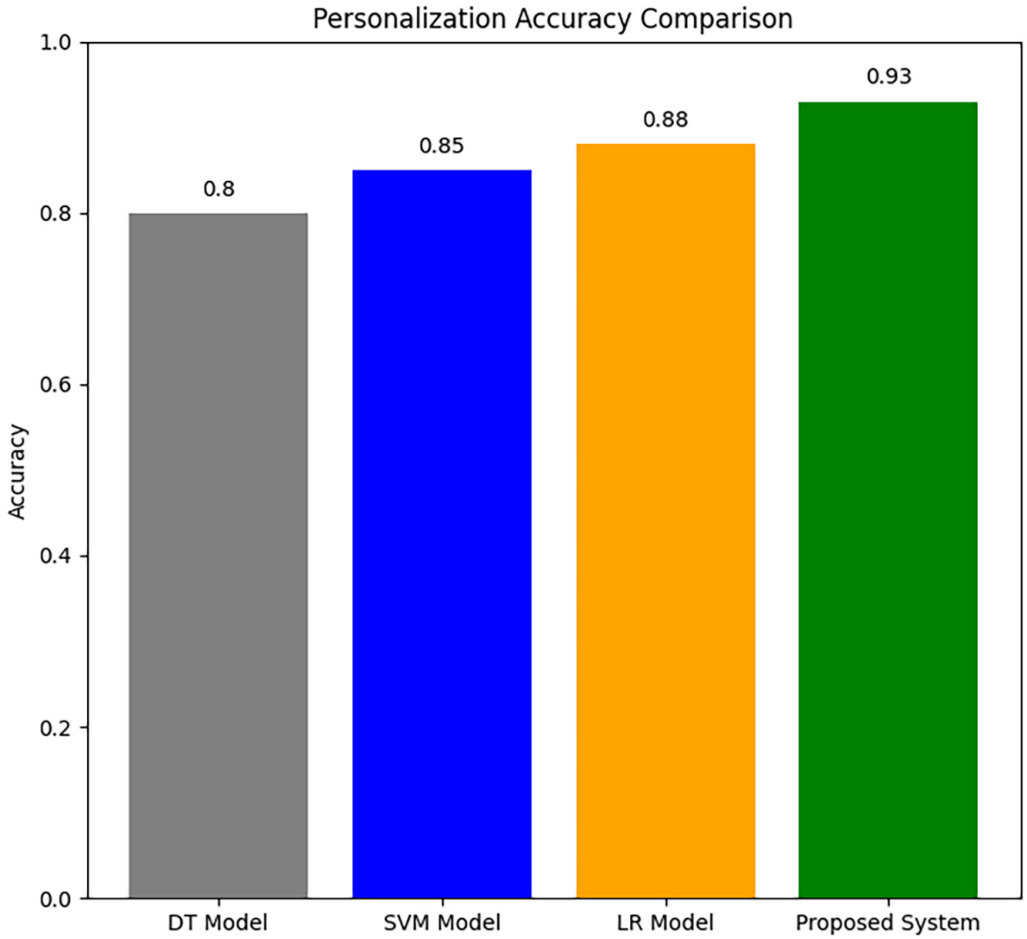

Fig. 6. Accuracy comparison of proposed model

The proposed generative AI-driven adaptive learning platform has several advantages against conventional learning tools based on assessments and outcomes. The data reveals that learners within the adaptive learning environment had superior scores on assessments, more engagement with the content, and satisfaction ratings than with traditional learning platforms. Several elements of the adaptive learning system contributed to these enhancements, including personalized learning pathways and intelligent feedback mechanisms. The findings suggest that the generative AI-powered adaptive learning platform creates a more effective, learner-centric educational experience than traditional non-adaptive learning systems, illustrating the success of the proposed generative AI-driven adaptive learning platform as shown in Figure 7.

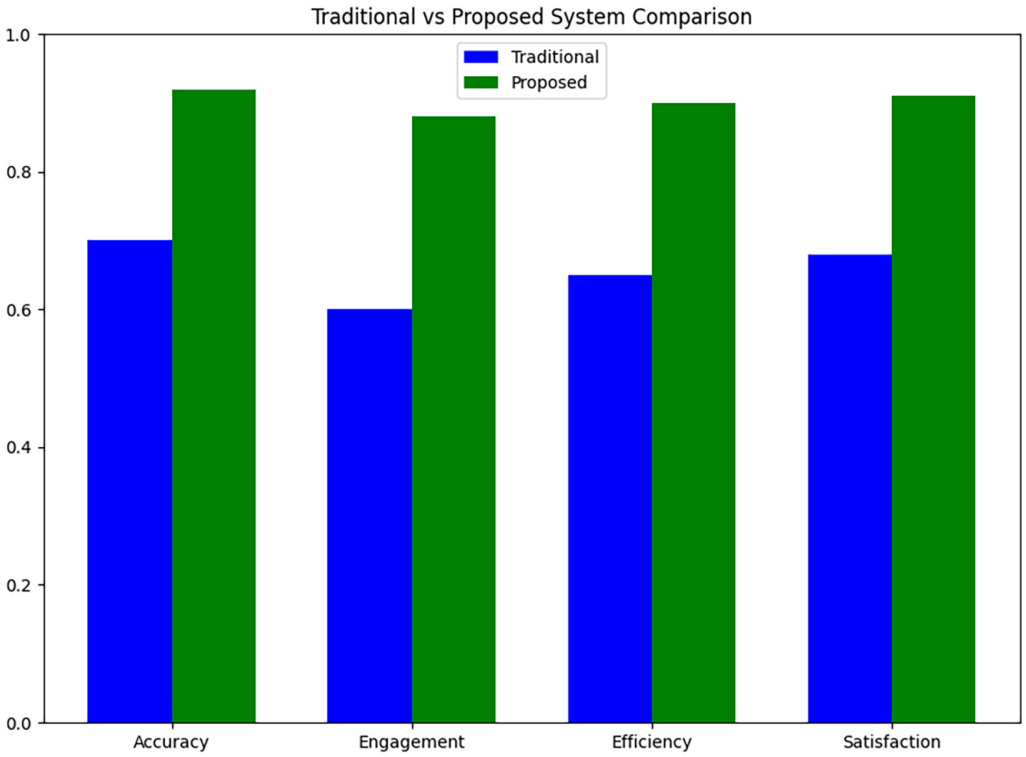

Fig. 7. Comparative analysis of proposed model with traditional model

5 CONCLUSION

In the article, we provide a description of the design, development, and evaluation of a generative AI-based interactive mobile learning system designed to increase learner engagement, increase the ability for the learner to acquire knowledge, and provide improved access to educational resources. The interactive mobile learning system is an intelligent adaptive learning environment that employs sophisticated natural language processing and machine learning techniques to adaptively change instructional materials, learning paths, and assessment strategies based on the needs, preferences, and performance of individual learners. By using a mobile-based learning platform, learners have access to real-time tutoring, generated, determined feedback, generated instructional materials, and interactive learning experiences, 24 hours a day, seven days a week. The system architecture consists of user profiling, a learning analytics engine, and a content generation process for creating dynamic course materials using GenAI, and providing feedback and making recommendations. These four components of the system work together to create personalized learning paths for individual learners and to enhance the ongoing learning processes of all learners. A thorough assessment of the proposed approach was conducted by utilizing multiple methods with students from a wide variety of educational backgrounds in order to measure the effectiveness of the AI-based adaptive learning system. Students' performance (effectiveness) was measured using both quantitative metrics and qualitative feedback, including measures of learning success (i.e., test scores), levels of engagement (i.e., how often students engage with the material), completion rate (number of tasks completed vs. total number of tasks assigned), and satisfaction (whether learners felt satisfied with their adaptive learning experience). Qualitative measures included survey responses and interview responses. Based on

the results of all evaluations performed, it has been found that AI-based adaptive learning systems provide greater motivation, more successfully comprehend course content, and a higher level of academic performance compared to the use of traditional mobile learning apps. In addition, learners who utilize this type of system feel more satisfied via personalized assistance and personalized timely feedback than those who utilize traditional methods. Additionally, it was shown that the system could scale and work well with multiple learning contexts and subjects. These results indicate that generative AI technologies have the possibility to change how mobile education will look in the future by enabling intelligent, learner-centered environments that will allow learners to participate in the learning process effectively and inclusively. The research enhances the body of knowledge relating to AI-enhanced education and provides practical information on how to implement or develop next-generation adaptive learning systems for mobility.

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