

AI-DRIVEN ADAPTIVE LEARNING'S EFFECT ON STUDENT MOTIVATION AND SELF-EFFICACY IN PUBLIC SECTOR UNIVERSITIES

Hina Iqbal^{*1}, Hafiza Ameenah Shaukat², Hajra Imran³

^{*1}PhD Scholar, IER, University of the Punjab, Lahore

²M.Phil Scholar, IER, University of the Punjab, Lahore

³Senior Lecturer, Education Department, GIFT University, Gujranwala

^{*1}hinascholar128@gmail.com, ²ameenashaukat444@gmail.com, ³hajra.imran@gift.edu.pk

Corresponding Author: *

Hina Iqbal

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ABSTRACT The integration of artificial intelligence (AI) in higher education has introduced new opportunities for personalized and adaptive learning. This study investigated the effects of AI-driven adaptive learning systems on student motivation and academic self-efficacy in public-sector universities in Pakistan. A quantitative research design was employed, and data were collected through a structured questionnaire administered to 200 students from four public universities in Lahore. The survey assessed students' exposure to AI-based adaptive learning tools, their motivation, and their academic self-efficacy. Descriptive and inferential statistical techniques, including correlation and regression analyses and independent-samples t-tests, were used to analyze the data. The findings revealed a significant positive relationship between AI-driven adaptive learning and both student motivation and academic self-efficacy. Regression results indicated that AI-based adaptive learning was a strong predictor of motivation and self-efficacy, accounting for a substantial proportion of the variance in student outcomes. Additionally, students with higher levels of AI use demonstrated significantly greater motivation and self-efficacy than those with lower levels of AI use.

Keywords: Artificial intelligence, adaptive learning, student motivation, academic self-efficacy

INTRODUCTION

Artificial Intelligence (AI) is transforming the educational sector by enabling innovative methods to personalize and enhance the learning experience. One of the most promising applications of AI in education is adaptive learning, which uses algorithms to personalize content delivery based on individual learners' needs. These systems aim to enhance student engagement, motivation, and academic self-efficacy, particularly in large and diverse educational settings such as public-sector universities in Pakistan (Naz, Malik, Farooq, & Munir, 2025). The potential benefits of AI-driven adaptive learning extend beyond academic performance. The potential benefits

of AI-driven adaptive learning extend beyond academic performance to psychological constructs such as motivation and self-efficacy, which are critical to students' academic success (Hussain, Zia, Zaki, & Iqbal, 2025).

Motivation has a very important role to play in student engagement, persistence and success. It is defined as the internal drive that guides and sustains goal-directed behavior, and it is particularly important in a university setting, where students are expected to complete complex tasks independently. In AI-driven adaptive learning, motivation is influenced by the level of personalization of the feedback and content these systems provide; thus, an

environment that facilitates students' inherent motivation to learn (Bandura, 1997; Ryan & Deci, 2000). Self-efficacy, a related psychological construct, denotes a student's belief in their capabilities to perform specific academic tasks (Bandura, 1997). Both self-efficacy and motivation play crucial roles in fostering a sense of ownership and autonomy over the learning process, which can lead to improved learning outcomes and higher academic performance (Hassan, Aslam, & Ahmad, 2025).

In Pakistani public-sector universities, where students commonly encounter challenges such as large class sizes, limited resources, and a lack of personalized attention from instructors, adaptive learning systems offer an opportunity to address these issues (Mahmood & Rehman, 2024). The AI-based systems adjust to the individual learning speeds, capabilities and weaknesses of the students and hence the specific support is offered to the student to improve engagement and motivation (Ullah, Hashim, Bandeali, & Akbar, 2025). By providing real-time feedback and adapting content delivery, these systems can positively impact students' academic self-concept by instilling a sense of progress and achievement, thereby increasing their self-efficacy (Hussain et al., 2025).

Several studies have examined the effectiveness of AI-based adaptive learning tools across various settings. For instance, studies conducted in Lahore have demonstrated that the application of AI tools has significantly enhanced the self-esteem of students as well the academic performance in both public and private universities (Naz et al., 2025). This is in line with the findings that have shown that AI-driven platforms have the potential to offer personalized learning experiences, enhancing student motivation and engagement by addressing individual needs and learning paces (Hassan et al., 2025). Additionally, research conducted in Pakistani universities has shown that students who use adaptive learning technologies show increased motivation and a greater sense of their ability to succeed academically (Pervaiz et al., 2025; Mustafa, Urooj, & Aslam, 2024).

However, the integration of AI-enabled adaptive learning in Pakistan's public sector

universities is not without difficulties. One of the biggest challenges is lack of infrastructure and digital literacy on the part of students and faculty members. Many institutions lack reliable internet connectivity, old hardware technology, and adequate technical support that affects the useful implementation of adaptive learning systems (Khan, 2024; Ghumman & Ansar, 2024). Furthermore, there tends to be resistance from faculty who may be skeptical about the role of AI in education, or who may not have the necessary training to effectively integrate these systems into their teaching practices (Arshad & Mahmood, 2022). Overcoming these barriers will necessitate comprehensive efforts, including the creation of digital literacy programs, the investment of more resources in infrastructure, and the professional development of educators (Qamar & Ullah, 2024).

Despite these challenges, the potential for AI to improve educational outcomes in Pakistan is significant. AI-powered adaptive learning systems not only help overcome educational inequalities but also ensure a more inclusive and personalized learning experience. When individualized learning paths are offered, these systems can contribute to decreasing the achievement gap, especially for students who might otherwise find themselves struggling in a traditional learning environment (Mahmood & Rehman, 2024). Furthermore, AI's capacity to monitor and evaluate student progress in real-time offers valuable insights that can be used to make informed choices about the best way to support students in achieving success.

Problem Statement

The integration of AI-driven adaptive learning systems into higher education has the potential to enhance student engagement, motivation, and self-efficacy. However, there is limited empirical evidence on the impact of these systems specifically within the context of public sector universities in Pakistan. Students in these institutions often face challenges such as large class sizes, lack of personalized learning support, and low academic self-efficacy. This research seeks to examine the effects of AI-driven adaptive learning on student motivation and self-efficacy in public sector universities in Pakistan.

Research Objectives

1. To determine the impact of AI-driven adaptive learning systems on student motivation in public sector universities in Pakistan.
2. To measure the effect of AI-based adaptive learning systems on students' academic self-efficacy.
3. To identify the challenges and barriers to implementing AI-driven adaptive learning systems in public sector universities in Pakistan.
4. To provide recommendations for the effective integration of AI-driven adaptive learning systems in higher education to enhance student outcomes.

Research Questions

- How does the use of AI-driven adaptive learning systems influence student motivation in Pakistani public sector universities?
- In what ways do AI-based adaptive learning systems affect students' academic self-efficacy in these institutions?
- What are the main challenges faced by public sector universities in Pakistan when implementing AI-driven adaptive learning systems?
- What strategies can be recommended to optimize the integration of AI-based adaptive learning systems in Pakistani public universities?

Literature Review

AI in Education

AI learning systems are supposed to customize learning experiences by changing the content to suit the requirements of a particular student (Naz, Malik, Farooq, & Munir, 2025). This customization is attained through the use of algorithms that evaluate the performance of the students and react by modifying the rate and difficulty of the material. The adaptive learning systems provide real-time feedback, which helps students to realize their progress and improvement points (Hassan, Aslam, & Ahmad, 2025). The ability to continually adjust to the reaction of a learner, these systems provide an environment that can be comfortable to motivate and engage the learner, which can break the tradition of assuming that

one-size-fits-all method of the traditional teaching process.

The AI-based adaptive learning system can provide a solution to these problems in Pakistan, where universities in the public sector tend to struggle with such issues as a large number of students in the classroom and a lack of individual attention (Ullah, Hashim, Bandeali, & Akbar, 2025). By offering customized assistance, these systems can be used to overcome educational imbalances because such assistance is needed particularly in resource-limited contexts in which faculty might not be able to support individual student needs effectively (Mahmood & Rehman, 2024).

Artificial Intelligence and Motivation in Higher Education

The student engagement, academic persistence and general student success are significantly related to motivation (Ryan & Deci, 2000). It has been shown that adaptive learning systems can also increase students' motivation by offering individualized learning processes and real-time feedback, which promotes a sense of competence and autonomy (Ryan & Deci, 2000). Applying to Pakistan, the researchers conducted by Naz et al. (2025) discovered that using AI tools had a significant influence on motivation in public and private Lahore based universities. These systems make the students feel they are more in control of the learning process and as a result, more intrinsically motivated, by making the learning process more customized and providing the necessary support at the right time.

Hussain, Zia, Zaki, and Iqbal (2025) examined the connection between AI-based learning aids and student motivation in Pakistan and discovered that adaptive learning systems were more likely to provide students with more engagement and involvement in learning because of personalized feedback. This individualistic strategy is aligned with the postulates of self-determination theory (SDT) that argues that motivation works well where the students feel autonomy, competence, and relatedness (Ryan & Deci, 2000). The AI systems in Pakistani public universities are likely to impact the development of these key aspects of helping to develop students through providing them with a highly personalized

learning experience and allowing the student to have a sense of connection with the learning process since in Pakistani universities students frequently have to experience large, impersonal classes.

Self-Efficacy and AI in Education

According to Bandura (1997), self-efficacy is that belief a person has in accomplishing certain tasks. Students with high levels of self-efficacy have a higher level of ambitious academic goals, put more effort and continue to struggle when faced with difficulties in education (Bandura, 1997). The effects of AI-based adaptive learning on student self-efficacy have been discussed in numerous studies, with positive outcomes. Specifically, AI systems with instant and tailored feedback have the potential to improve the self-efficacy of students by enabling them to monitor their achievements and support the self-concept of their academic skills (Hassan et al., 2025).

The significance of self-efficacy in student performance is evident in Pakistani universities, as many students struggle with confidence due to educational disparities and limited access to individualized learning support (Pervaiz et al., 2025). According to research provided by Mahmood and Rehman (2024), AI-powered adaptive learning systems can help minimize these obstacles by offering students the tools they need to achieve success at a pace that improves their self-efficacy. The real-time feedback helps students to believe in their academic abilities and hence the improved results when they observe significant changes in their performance (Mahmood & Rehman, 2024).

The positive influence of AI on student engagement, which is closely linked to self-efficacy, is also noted in a study by Muslim, Saleem, Zahra, and Touseef (2025). Virtual learning environments allow AI systems to adapt to the needs of students and this gives them a feeling of competence and control which consequently enhances their self-efficacy. This is especially true in the Pakistani state universities, where students tend to disengage, because of the difficulties of the traditional, lecture-based methods of teaching (Ghumman & Ansar, 2024).

Although the idea of AI-based adaptive learning systems has a huge potential in Pakistan, there are a number of challenges that are encountered in implementation. One of the problems is the absence of the infrastructure, such as unstable internet connection and old hardware that restricts the usefulness of AI tools (Qamar & Ullah, 2024). Also, the faculty frequently experiences opposition, which might be due to deficiencies in AI technologies training or their unwillingness to embrace the use of such tools in the classroom (Arshad and Mahmood, 2022). These impediments hinder the implementation of AI in most public-sector universities, particularly in rural communities where resources are even scarcer.

Regardless of these issues, a number of studies have highlighted the need to overcome those hurdles in order to optimize the potential of AI-based adaptive learning. Indicatively, in a study by Khan, Manzoor, and Khatoon (2025) there is a call to invest in the digital infrastructure and faculty capacity because the adoption of AI in public universities cannot be successfully integrated without them. On the same note, Ghumman and Ansar (2024) state that the successful implementation of AI technologies is impossible without both technological investment and the shift in the cultural environment of educational institutions, i.e. the overcoming of technophobia and the increase in the digital literacy of both students and educators.

The Future Of AI-Based Adaptive Learning in Pakistan

In the future, AI-based adaptive learning systems can shape the future of education in Pakistan by providing a more personalized, engaging, and efficient learning experience. According to Mustafa, Urooj, and Aslam (2024), AI may be introduced into Pakistan's higher education system by 2030, thereby making the learning process more individualized and interactive. Nonetheless, to ensure that this vision becomes a reality, we need to address issues related to digital literacy, faculty development, and infrastructure.

Besides, AI integration in education should be followed by a detailed policy framework that guarantees equal access to these technologies to all universities, especially in rural regions (Lawal

and Sain, 2024). The AI systems can contribute to lessening education inequalities and enhance a more inclusive and productive learning setting, as Pervaiz et al. (2025) emphasize, and it should be carefully planned and resourced.

Theoretical Framework

This study is grounded in Self-Determination Theory (SDT) (Ryan & Deci, 2000), which emphasizes that motivation is fostered when students experience autonomy, competence, and relatedness. AI-driven adaptive learning systems promote autonomy by personalizing learning paths, competence through real-time feedback, and relatedness by engaging students

based on their needs (Hussain, Zia, Zaki, & Iqbal, 2025).

Additionally, Social Cognitive Theory (SCT) (Bandura, 1997) highlights that self-efficacy—students' belief in their ability to succeed—plays a key role in academic motivation. AI systems enhance self-efficacy by providing personalized support, guiding students toward success (Hassan, Aslam, & Ahmad, 2025).

Cognitive Load Theory (Sweller, 2020) suggests that adaptive systems reduce cognitive overload by presenting content at the right level of difficulty, helping students manage learning effectively (Ameer Muhammed Moeed Mahdi et al., 2025).

Conceptual Framework

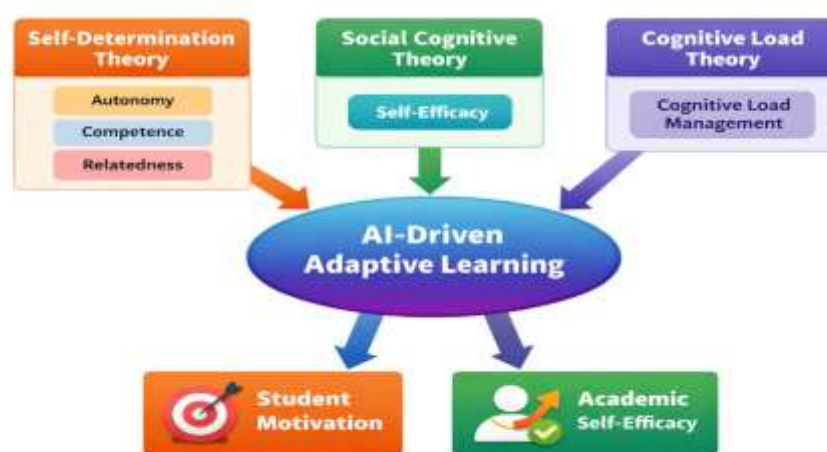


Figure 1

Research Methodology

The research employed a quantitative approach to examine the impact of AI-driven adaptive learning on student motivation and self-efficacy at public-sector universities in Lahore. Data was collected through surveys administered to a sample of 200 students across four public universities. The survey assessed students' experiences with AI-based adaptive learning tools and their perceptions of motivation and self-efficacy. Statistical analysis, including

descriptive and inferential methods, was employed to analyze the data and determine the relationship between AI-driven adaptive learning and student outcomes. The research adhered to ethical standards to ensure the privacy and confidentiality of all participants. Informed consent was obtained from all respondents, explaining the purpose of the study, the voluntary nature of participation, and the confidentiality of their responses.

Results and Findings

Table 1 Correlation between AI-Driven Adaptive Learning, Student Motivation, and Self-Efficacy

Variables	AI-Driven Adaptive Learning	Student Motivation	Academic Self-Efficacy
AI-Driven Adaptive Learning 1			

Student Motivation	.58**	1	
Academic Self-Efficacy	.62**	.66**	1

Note. N = 200. $p < .01$

The statistical significance of the positive correlations between AI-driven adaptive learning and student motivation and academic self-efficacy was assessed. AI-driven adaptive learning showed a moderate positive correlation with student motivation ($r = .58$, $p < .01$) and a strong positive correlation with academic self-efficacy ($r = .62$, $p < .01$). In

addition, a strong, positive relationship was found between student motivation and academic self-efficacy ($r = .66$, $p < .01$). These findings suggested that greater exposure to AI-based adaptive learning systems was related to higher levels of motivation and greater beliefs of academic capability in students in the public sector universities.

Table 2 Simple Linear Regression Analysis Predicting Student Motivation from AI-Driven Adaptive Learning

Predictor	B	SE	β	t	p
Constant	1.42	.21	—	6.76	.000
AI-Driven Adaptive Learning	.53	.06	.58	8.83	.000
Model Summary					
R	.58				
R ²	.34				
Adjusted R ²	.33				
F		78.03			
p		.000			

The simple linear regression analysis showed that AI-driven adaptive learning was a significant predictor of student motivation. The model accounted for 34% of the variance in student motivation ($R^2 = .34$, $F = 78.03$, $p < .001$). The standardized regression coefficient ($\beta = .58$, $p < .001$) indicated a highly significant positive effect, demonstrating that increased

use of AI-based adaptive learning systems significantly increased student motivation. This finding supported the research objective of determining the impact of AI-based adaptive

learning on student motivation in the public sector universities of Pakistan.

Table 3 Simple Linear Regression Analysis Predicting Academic Self-Efficacy from AI-Driven Adaptive Learning

Predictor	B	SE	β	t	p
Constant	1.31	.19	—	6.89	.000
AI-Driven Adaptive Learning	.57	.05	.62	10.14	.000
Model Summary					
R	.62				
R ²	.38				
Adjusted R ²	.37				

Predictor	B	SE	β	t	p
F	102.82				
p	.000				

The results of the regression showed further that the AI-driven adaptive learning has a significant predictive effect on students' academic self-efficacy. The model explained 38% of the variance in academic self-efficacy ($R^2 = .38$, $F = 102.82$, $p < .001$). The standardized beta value ($\beta = .62$, $p < .001$) indicated a strong positive effect indicating that

students who engaged more often with AI-based adaptive learning tools reported increased levels of confidence in their academic abilities. These results highlighted the success of the adaptive learning systems in strengthening the self-efficacy of the students.

Table 4 Independent Samples t-Test Comparing Motivation Levels by AI Usage Intensity

Group	N	Mean	SD	t	p
Low AI Usage	96	3.21	.54		
High AI Usage	104	3.78	.49	7.52	.000

A statistically significant difference in student motivation was found between students with low and high levels of AI-driven adaptive learning use, as assessed by an independent-samples t-test. Students in the high AI usage group had higher scores on motivation ($M = 3.78$, $SD = .49$) than the low usage ($M = 3.21$,

$SD = .54$), $t(198) = 7.52$, $p < .001$. This finding suggested that the more students were exposed to AI-driven adaptive learning systems, the more they were motivated, supporting the hypothesis that adaptive technologies can be used to encourage engagement in learning.

Table 5 Independent Samples t-Test Comparing Self-Efficacy Levels by AI Usage Intensity

Group	N	Mean	SD	t	p
Low AI Usage	96	3.18	.57		
High AI Usage	104	3.86	.51	8.61	.000

Similarly, the results of the t-test showed a significant difference between the academic self-efficacy of students with different levels of usage of AI-driven adaptive learning. Students who reported high usage of AI-based adaptive learning systems had significantly higher self-efficacy ($M = 3.86$, $SD = .51$) compared to

students who had low usage ($M = 3.18$, $SD = .57$), $t(198) = 8.61$, $p < .001$. This result suggested a positive role of AI-driven adaptive learning in the confidence students have when managing academic tasks and challenges.

Table 6 Multiple Regression Analysis Predicting Student Outcomes

Predictor	Motivation (β)	Self-Efficacy (β)
AI-Driven Adaptive Learning	.41**	.45**
Perceived Ease of Use	.29**	.27**

Predictor	Motivation (β)	Self-Efficacy (β)
Instructor Support	.22*	.19*
R ²	.48	.52
F	59.24	68.17
p	.000	.000

Note. * $p < .05$, ** $p < .01$

The results of the multiple regression analysis showed that AI-driven adaptive learning was the best predictor of student motivation ($\beta = .41$, $p < .01$) and academic self-efficacy ($\beta = .45$, $p < .01$), controlling for perceived ease of use and instructor support. The model accounted for 48% of the variance in student motivation and 52% of the variance in academic self-efficacy, both of which were statically significant ($p < .001$). These results showed that although usability and instructional support had important roles, AI-based adaptive learning has a dominant influence on improving student motivation and self-efficacy in public sector universities.

Discussion

The current paper investigated the impact of adaptive learning systems relating to AI on student motivation and academic self-efficacy in the context of Pakistani public sector universities. The results showed that adaptive learning through AI proved to be significantly beneficial in motivating and increasing the self-efficacy of university learners. The findings add up to the mounting local empirical literature on the transformative role of artificial intelligence in higher education in developing nations including Pakistan.

The correlation found between AI-driven adaptive learning and student motivation was positive, which stands in the direction of the correlation found with the study conducted in Pakistan, which highlights the motivational advantages of the AI-facilitated learning environments. According to Hussain et al. (2025), AI-based learning tools were found to enhance the motivation and academic self-concept of students with great effectiveness due to the personalized feedback and adaptive learning goals offered. Similarly, Ahmed et al.

found that AI-enabled adaptive learning systems enhanced learner engagement and intrinsic motivation by supporting individual learners' needs (Ahmed et al., 2025). The present work expands the results of the existing literature by proving that the motivational benefits, too, can be observed in the public sector universities, as these institutions are often affected by the issues of overcrowded classes and the lack of instructional resources. Theoretically, the findings can be attributed to the Self-Determination Theory (SDT) that states that the intrinsic motivation is basically driven by autonomy, competence, and relatedness (Ryan and Deci, 2000). Adaptive learning systems based on AI ensure autonomy since students have the opportunity to learn their way, whereas individual feedback increases the feeling of competence. The statistically significant increase in motivation rates of the students, who were exposed to the methods of AI-based systems more often, serves as an indication that the adaptive technologies, in their turn, facilitate these psychological needs, and, therefore, enhance the intrinsic motivation in the learning process.

Other findings of the study were that adaptive learning, which shapes the influence of AI, had a strong positive effect on students' academic self-efficacy. The result is consistent with the findings of Naz et al. (2025), who noted that the application of AI tools had positive effects on students' self-esteem and performance in universities in Lahore. Similarly, Pervaiz et al. (2025) underscored that academic self-efficacy mediates the relationship between student achievement and academic confidence. These conclusions are supported by the current study, which has shown that adaptive learning technologies contribute to students' belief in

their ability to effectively cope with academic assignments.

It may also be explained by the intricate predictive relationship between AI-governed adaptive learning and self-efficacy, given the continuous feedback and tailored support delivered by AI systems. The authors observed that the use of AI-based platforms could enhance student performance by detecting learning gaps and providing interventions (Hassan et al., 2025). These features reduce information overload and enable students to experience mastery, an essential source of self-efficacy. Adaptive systems based on AI seem to offset this drawback in universities in the public sector where personalized instructor attention is usually insufficient.

The effectiveness of adaptive learning systems was also supported by the comparison of high and low levels in students who use AI. Students that were more involved in AI-driven learning ended up with much higher motivation and self-efficacy compared to those who had little exposure. Such findings are agreeable with those of Khan (2024), who observed that the adaptive learning technology, along with individual feedback, increased student engagement considerably, especially with proper digital literacy in possession. It implies that such AI-driven solutions are the most effective when students have low technological skills, which is a key matter to be considered in practicing such implementation in higher education institutions of the population.

The results of the multiple regression showed that AI-based adaptive learning was the best predictor of motivation and self-efficacy despite the consideration of perceived ease of use and instructor support. This lends credence to the fact that AI-driven adaptive environments will be at the center of determining higher education by 2030 as suggested by Mustafa et al. (2024). Although instructor support and usability of the system are critical, the responsive and adjustive quality of AI systems seems to influence student achievement more significantly. This highlights the necessity to incorporate the AI technologies not only as the auxiliary devices but as the elements of the instruction design.

Irrespective of these good results, the results should be viewed as per the contextual issues

that have been encountered by the public sector universities in Pakistan. Arshad and Mahmood (2022) underscored the fact that the adoption of autonomous and technology-based approaches to learning by teachers can be associated with resistance, a lack of training, and various infrastructural limitations. Equally, the Qamar and Ullah (2024) have cited challenges that include a lack of institutional support, the lack of digital infrastructure, as well as lack of access to professional development opportunities by faculty in the public universities. Unless these issues are properly taken into account, they can limit the potential of the AI-powered adaptive learning. Moreover, although AI-based adaptive learning systems promise to help decrease educational inequalities, as supported by Mahmood and Rehman (2024), equitable access is also an important issue. The students with poor backgrounds might be at a disadvantage with little access to digital devices or steady internet connectivity. In the absence of inclusion policies and institutional investor-supported changes, the dividends of AI-directed learning would be culturally biased toward more digital literate and more digitally available students, which would strengthen historical disparities.

The policies of interest also including the study are important implications of this study, as pertaining to curriculum design. The articles by Ullah et al. (2025) highlighted the importance of integrating AI into the structure of the curriculum in order to facilitate adaptive and personalized learning processes. The noted positive changes in this study indicate that policymakers and government bodies in charge of higher learning must focus on the strategic adoption of adaptive learning systems operated by AI in state Universities. These are the alignment of curricula to the adaptive technologies, faculty training and ethical use of student data.

Conclusion

The research provides empirical evidence in favor of the importance of AI-based adaptive learning in increasing student motivation and self-efficacy in Pakistani universities of the public sector. As seen through statistically significant changes in the main aspects of the results, i.e. psychological and academic

achievement, the study substantiates the thesis that AI technologies can help overcome the old difficulties in higher education, including the problem of the high volume of classes attended and the inability to provide students with personalized care. Nevertheless, the effective introduction of such systems depends on the specific attention to contextual barriers, institutional preparedness and equity issues.

Recommendations

- Public sector universities should integrate AI-driven adaptive learning systems into regular teaching practices to provide personalized learning support and enhance student motivation and academic self-efficacy.
- Faculty members should be provided with continuous professional development and training programs to effectively use AI-based adaptive learning tools and align them with course objectives.
- Universities should invest in improving digital infrastructure, including reliable internet access and learning management systems, to ensure the effective implementation of AI-driven learning technologies.
- Policymakers and higher education authorities should develop clear guidelines and ethical frameworks to ensure responsible, transparent, and equitable use of AI-driven adaptive learning systems.
- Efforts should be made to enhance students' digital literacy through orientation programs and workshops to maximize the benefits of AI-based adaptive learning tools.

Limitations of this study

1. The study was limited to public sector universities in Lahore, which may restrict the generalizability of the findings to other regions of Pakistan.
2. Data were collected through self-reported questionnaires, which may be subject to response bias.
3. The cross-sectional design of the study did not allow for examination of long-term effects of AI-driven adaptive learning.

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