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The impact of adaptive and interactive ai tools on student learning: From digital literacy to advanced skills

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Abstract

Globally, learning paradigms are evolving due to the integration of artificial intelligence (AI) into higher education. This study investigates the effects of Digital Literacy, Interactive AI Tools, and Adaptive Learning Technologies on Student Skills (SS), such as critical thinking, problem-solving, and learning performance. Data were gathered from 339 undergraduate students enrolled in private universities in Bahrain using a quantitative, cross-sectional design. The measurement model was verified using structural equation modeling (SEM), which produced excellent convergent validity (AVE = 0.614–0.748) and high reliability (Cronbach's α = 0.871–0.955). With R^2 = 0.733, the structural model showed significant explanatory power, explaining 73.3% of the variation in student abilities across ALT, IAT, and DL. IAT had the greatest impact (β = 0.523, t = 6.510, $p < 0.001$), followed by ALT (β = 0.179, t = 3.955, $p < 0.001$) and DL (β = 0.160, t = 3.421, $p < 0.001$), according to path analysis. Findings provide new empirical data in the GCC context and align with international studies, such as Lee et al. [1] and Asy'ari and Sharov [2]. The research emphasizes how interactive AI solutions and digital literacy can be strategically used to improve 21st-century skills. These findings quantitatively show that combining ALT, IAT, and DL may significantly and consistently improve student skill development in higher education, offering valuable insights for policymakers and educational leaders in Bahrain.

Keywords: Adaptive learning technologies, Artificial intelligence, Bahrain, Digital literacy, Higher education, Interactive AI tools, Student Skills.

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1. Introduction

The emergence of Adaptive Learning Technologies (ALT) and Interactive AI Tools (IATs) has significantly transformed educational environments, enhancing fundamental student skills (SS) such as learning performance, problem-solving, critical thinking, and technology-driven competencies. ALT tailors instructional material by analyzing student behavior and adjusting speed and difficulty in real time, while IATs such as conversational chatbots and intelligent tutoring systems provide dynamic and responsive feedback [3].

Empirical evidence highlights the effectiveness of ALT: in a comprehensive review of 69 studies, 59% indicated enhanced academic performance and 36% noted increased student engagement when adaptable technologies were used in higher education environments [4]. A field trial in China revealed that the "Yixue" adaptive system markedly surpassed both conventional classroom education and another alternative adaptive platform in enhancing mathematics and English proficiency [5]. Likewise, in business statistics courses, adaptive learning consistently improved student performance and satisfaction compared to traditional instructional methods [6, 7]. Interactive AI tools, such as AutoTutor and generative conversational agents, enhance competence development via scaffolded interaction and real-time teaching. AutoTutor showed average effect sizes of 0.8 in conceptual learning improvements among college students, especially in critical thinking and deep reasoning areas [8, 9]. Nonetheless, recent studies warrant caution. Research indicates a negative link between frequent use of AI tools and critical thinking skills ($r = -0.68$, $p < 0.001$), due to cognitive offloading, where dependence on AI diminishes involvement in analytical activities [10].

An increasing amount of research suggests that digital literacy is fundamental in influencing the efficacy of using ALT and IAT by students. Enhanced digital literacy is intrinsically associated with more efficient engagement with educational AI technology and improved learning outcomes. In contrast, students with inadequate digital literacy often interact passively with AI technologies, hindering their capacity to cultivate critical thinking and autonomous problem-solving abilities [11]. Comparative investigations across educational settings demonstrate that adaptive and interactive technology can provide better learning outcomes than lecture-based and non-interactive techniques. Meta-analytical studies in STEM fields indicate that active learning, facilitated by AI technologies, enhances course performance by around 0.47 standard deviations and decreases failure rates from 32% to 21% compared to conventional lecturing [12].

1.1. Research Objectives

To address the gap identified here, this study seeks to:

Examine the impact of adaptive learning technologies on enhancing student skills, including learning performance, problem-solving, critical thinking, and technology-driven competencies.

Investigate the influence of Digital Literacy on Student Skills within AI-driven educational environments.

Evaluate the effect of Interactive AI Tools on Student Skills and assess their role in competency development.

2. Literature Review

2.1. Introduction to AI Tools in Education

A recent study highlights that the global adoption of artificial intelligence in education is witnessing remarkable expansion, with AI-driven learning technologies anticipated to reach a market valuation of USD 20 billion by 2027 [13]. Research from leading academic institutions in the United States, China, and Europe consistently indicates that adaptive learning technologies and interactive AI tools improve student skills, encompassing learning performance, critical thinking, and technology-related skills [14-16]. ALT facilitates customized learning trajectories aligned with individual advancement, while IAT provides interactive, dialogue-driven engagement that fosters critical thinking and cooperative problem-solving. Consistent with these global results, a recent study in the Gulf Cooperation Council (GCC) countries underscores the rapid integration of AI in higher education. Saudi Arabia's Vision 2030 incorporates intelligent tutoring systems in colleges, which have boosted STEM capabilities by as much as 35% [17]. The UAE has adopted adaptive platforms that have enhanced student engagement rates by 40% in a blended learning settings [18]. However, empirical research in Bahrain remains limited, resulting in an insufficient understanding of the contextual appropriateness and pedagogical effectiveness of ALT and IAT. This study aims to fill this gap by providing evidence-based insights consistent with global standards while addressing regional research deficiencies.

2.2. Adaptive Learning Technologies and Student Skills

Adaptive Learning Technologies have emerged as revolutionary instruments in contemporary education, dynamically modifying learning trajectories to correspond with students' immediate performance and personalized requirements. ALT utilizes data-driven algorithms to adapt instructional material, manage pace, and provide focused feedback, hence promoting mastery learning and self-regulated educational advancement. In a recent meta-analysis, Angelova-Stanimirova and Lambovska [19] indicated that 59% of ALT implementations substantially improved academic achievements, while 36% increased student engagement, illustrating ALT's ability to enhance both cognitive and behavioral aspects of learning [20]. These findings were supported by empirical evidence from China, demonstrating that students using the Yixue adaptive system achieved significantly higher scores in mathematics and English than their counterparts in traditional instructional environments or those using non-adaptive platforms [21].

Favorable developments have been observed in higher education environments. For example, Rincon-Flores et al. [22] reported consistent enhancements in university statistics courses after the implementation of ALT, corroborating previous findings by Ludwig [23], who indicated an average effect size of 0.47 SD increase in student performance within active and adaptive learning contexts. Taken together, these findings underscore ALT's effectiveness in improving conceptual mastery, critical thinking, and problem-solving skills.

In the GCC region, the use of ALT is progressively rising as an element of comprehensive digital transformation initiatives. Saudi Arabia's Vision 2030 expressly integrates AI-driven educational platforms to enhance STEM capabilities and modernize instructional delivery [24]. Despite these developments, few empirical studies have assessed the direct impact of ALT on student abilities in Bahrain and other Gulf nations. This disparity highlights the need for localized research to evaluate the efficacy of ALT, facilitating evidence-based policy formulation and optimizing the educational advantages of adaptive learning technology.

2.3. Interactive AI Tools and Skill Enhancement

Interactive AI tools, including intelligent tutoring systems, conversational chatbots, and AI-driven feedback mechanisms, have become essential innovations in contemporary education. These technologies provide individualized learning assistance, allowing students to receive prompt, tailored instruction that enhances comprehension and critical thinking abilities. Empirical research on AutoTutor, a prominent intelligent tutoring system, has repeatedly demonstrated significant improvements in conceptual learning, with an average effect size of 0.8, indicating notable enhancements in understanding and problem-solving skills Alrakhawi et al. [25]. Dervin et al. [26] investigated interactive learning assistants at Taiwanese colleges and reported an 18% improvement in analytical reasoning abilities compared to conventional lecture-based teaching, highlighting ILAs' ability to augment higher-order cognitive skills.

Despite these encouraging results, concerns have been expressed about the naive dependence on generative chatbots. by Typografia et al. [27] documented a significant negative association ($r = –0.68$, $p < 0.001$) between excessive chatbot use and critical thinking skills, a phenomenon ascribed to cognitive offloading, whereby learners increasingly rely on automated replies instead of exercising independent reasoning. This underscores the dual nature of IAT: well-designed systems can offer significant learning experiences, whereas poorly executed or excessively used technologies may unintentionally obstruct the cultivation of critical skills like analytical thinking and autonomous problem-solving.

The findings indicate that the design, pedagogical integration, and contextual application of IAT are essential in shaping educational outcomes. Future research, especially within GCC environments, should investigate effective implementation strategies that balance AI-driven supervision with opportunities for independent cognitive engagement, ensuring that IAT realizes its potential in enhancing 21st-century student skills.

2.4. Digital Literacy as a Predictor of AI Effectiveness

Digital literacy functions as a fundamental skill that empowers students to proficiently use AI-enhanced instructional resources. It includes the capacity to access, assess, and utilize digital resources for problem-solving and academic improvement. Recent studies highlight the critical role of deep learning in shaping educational outcomes in AI-enhanced settings. Yaseen et al. [11] discovered that students with high digital literacy markedly demonstrated greater engagement and performance when using adaptive learning technologies and interactive AI tools, underscoring the importance of digital literacy in optimizing the educational benefits of AI. Sharma et al. [28] found a positive correlation ($r = 0.571$, $p < 0.05$) between the use of AI tools in digital learning and perceived learning effectiveness among university students in India, highlighting the importance of digital competencies in harnessing emerging technologies in higher education.

Although GCC nations possess strong digital infrastructure, with internet penetration in Saudi Arabia surpassing 97%, the proficiency in digital skills among students is inconsistent. In 2023, UNICEF reported that only 40% of Gulf students demonstrated advanced technological competency, suggesting that limited digital literacy may hinder students' capacity to effectively use AI-enhanced learning systems [29]. The Ministry of Education in Bahrain has recognized this gap, making digital learning development a strategic priority in its 2030 Vision for educational reform [30]. Nonetheless, there is a scarcity of empirical research directly assessing the impact of DL on improving student abilities in AI-driven environments. It is crucial to address this research gap to understand how enhancing digital literacy might improve the efficacy of ALT and IAT in promoting critical thinking, problem-solving, and overall academic achievement in the GCC region.

2.5. Hypotheses Development

2.5.1. Adaptive Learning Technologies and Student Skills

Adaptive Learning Technologies have emerged as transformational educational tools, leveraging artificial intelligence to customize teaching by dynamically modifying content, sequencing, and feedback to address the distinct requirements of each student [31]. These systems evaluate real-time student performance data to provide customized educational experiences that encourage self-directed learning, mastery of ideas, and focused remediation as needed. Empirical research has continuously shown ALT's beneficial impact on academic performance and skill enhancement. Shi et al. [32] found that students using an adaptive platform significantly outperformed their peers in mathematics and English, attaining statistically significant improvements compared to those in conventional classroom environments. The enhancements were primarily ascribed to the platform's capacity to customize content and provide ongoing, data-informed feedback. Likewise, Rincon-Flores et al. [22] discovered that the incorporation of ALT into higher education curricula led to improved conceptual comprehension and critical thinking skills. The adaptive system's tailored learning paths and prompt corrective feedback significantly enhanced student engagement and problem-solving skills. These results indicate that ALT significantly contributes to the development of student skills, including enhanced learning performance, sophisticated analytical thinking, and technology-based competencies vital for 21st-century education. By providing customized learning experiences, ALT enables students to become engaged, self-directed learners, thereby promoting enhanced cognitive development and academic achievement.

$H_{1:}$ Adaptive Learning Technologies have a significant positive effect on Student Skills.

2.5.2. Interactive AI Tools and Student Skills

Interactive AI tools, such as intelligent tutoring systems, conversational agents, and automated feedback mechanisms, are widely acknowledged for their revolutionary impact on promoting active participation and collaborative learning in educational settings [33]. These technologies provide immediate, tailored assistance that enhances student engagement, promotes a profound comprehension of topics, and fosters the development of advanced cognitive abilities. AutoTutor, a prominent intelligent tutoring system, has shown significant effectiveness in enhancing student understanding and reasoning skills, with research reporting an average effect size of 0.8, indicating considerable educational benefits [25]. Similarly, Kulaksız [34] discovered that the incorporation of Interactive Learning Assistants in university classes improved students' problem-solving ability by 18% compared to conventional lecture-based education. These results highlight the effectiveness of IAT in enhancing analytical thinking, cognitive flexibility, and skill development in higher education environments. Notwithstanding these favorable results, Karamuk [35] noted that several academics have expressed concerns about overreliance on chatbots, suggesting that excessive reliance on AI-generated replies may undermine autonomous reasoning and critical thinking. Nonetheless, existing research indicates that when well-planned and pedagogically integrated, IAT can substantially enhance student abilities, highlighting its significant role as a powerful educational innovation in contemporary learning environments.

$H_{2:}$ Interactive AI Tools have a significant positive effect on Student Skills.

2.5.3. Digital Literacy and Student Skills

Digital literacy is described as an individual's ability to identify, assess, and proficiently use digital technology for educational and problem-solving objectives. It includes technical proficiency, critical assessment of digital content, and the capacity to implement technology-based solutions for academic assignments. Recent empirical research identified deep learning as a critical factor influencing student achievement in AI-enhanced learning settings. Yaseen et al. [11] found that university students with higher digital literacy demonstrated significantly greater engagement with AI-enhanced instructional platforms. This increased engagement led to higher critical thinking skills and technology-driven competencies, demonstrating that DL allows students to navigate adaptive platforms more effectively and use interactive AI technologies proficiently. Joseph et al. [36] found a significant positive connection ($r = 0.571$, $p < 0.05$) between digital literacy and academic performance in AI-assisted courses, highlighting digital literacy as a pivotal determinant of success in contemporary education. Although digital infrastructure is widely available in the GCC countries, including Bahrain, discrepancies in digital literacy levels among schoolchildren persist [37]. This gap hinders the full realization of the benefits of educational technology. Thus, students with higher levels of digital literacy are better equipped to develop advanced 21st-century competencies, including problem-solving, analytical thinking, and technology adaptation, which are vital in increasingly AI-integrated educational settings.

$H_{3:}$ Digital Literacy has a significant positive effect on Student Skills.

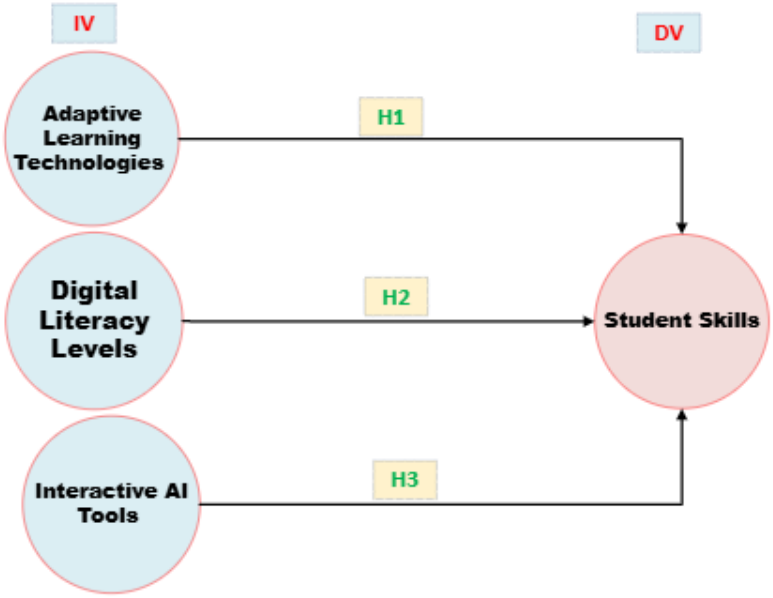

Figure 1.
Conceptual Framework.
Note: Adaptive Learning Technologies and Interactive AI Tools, Digital Literacy, Student Skills.

3. Methodology

3.1. Research Design

This research paper employed a quantitative, cross-sectional design to examine the direct effects of Adaptive Learning Technologies, Interactive AI Tools, and Digital Literacy on student skills. A structural equation modeling (SEM) approach was employed to simultaneously assess the potential relationships and quantify the influence of each construct on student competencies. This method was chosen for its capacity to handle several interrelated dependent relationships, while addressing measurement errors and validating latent constructs.

3.2. Population and Sampling

The study was conducted among undergraduate students enrolled in various private institutions in Bahrain, representing a range of academic disciplines such as business, engineering, information technology, and education. The universities were selected for their progressive adoption of AI-based educational platforms and diverse student demographics, making them an appropriate context for analyzing the effects of AI tools on higher education.

A stratified random sampling procedure was used to ensure proportional representation from each college within the university. Based on Contrino et al. [6] table for establishing sample size and SEM requirements, Renthlei and Lallawmkima [38] reported that a minimum of 339 respondents is required to obtain reliable parameter estimates and adequate statistical power. Researchers continued distributing questionnaires until the required number of responses was obtained. Of the 339 questionnaires received, 85% were usable.

3.3. Instrument Development

The study's questionnaire was developed using established scales as follows:

- Adaptive Learning Technologies: Assessed with a 6-item scale adapted from Contrino et al. [6] and Gyonyoru and Katona [39], emphasizing customization, content adaptability, and real-time feedback.
- Interactive AI Tools: Assessed with a 7-item scale derived from Bauer et al. [40] and Peng and Zhou [41], measuring conversational assistance, collaborative functionality, and AI-driven feedback mechanisms.
- Digital Literacy: Measured with a 5-item scale derived from Yaseen et al. [11]. The items assessed competencies in locating, evaluating, and using digital resources.
- Student Skills: Measured with an 8-item scale to assess learning performance, problem-solving, critical thinking, and technology-related competencies Harrell [42]. All items employed a five-point Likert scale (1 = strongly disagree, 5 = strongly agree).

3.4. Data Collection Procedure

Data was gathered during the Fall 2025 semester. Participants received both paper-based and online questionnaires, along with an informed consent statement assuring voluntary participation and confidentiality of their responses. To reduce common-method bias, the questionnaire randomized item order and included negatively worded questions. Before data collection began, the university's Research Ethics Committee granted approval for the study.

3.5. Data Analysis

Data were analyzed using SPSS 28 for descriptive statistics and SmartPLS 4 for structural equation modeling. The sample was randomly split and analyzed as follows:

1. Measurement Model Assessment: Reliability and validity were assessed using Cronbach's alpha, Composite Reliability (CR), Average Variance Extracted (AVE), and discriminant validity based on the Fornell-Larcker criteria.

2. Structural Model Evaluation: Path coefficients (β), t-values, and p-values were calculated using 5,000 bootstrap resamples to assess the three direct hypotheses (H1–H3). Model fit indices, including outer loadings, Cronbach's alpha, average variance extracted (AVE), and R^2, were presented to evaluate explanatory power and prediction accuracy.

3.6. Ethical Considerations

The researchers complied with the ethical standards established by Ebrahimi et al. [43]. Participation was voluntary, informed consent was obtained, and answers were anonymized to safeguard participant privacy. Students were notified that the data would be used only for academic purposes.

4. Results

As presented in Table 2 the measurement model demonstrates robust reliability and convergent validity across all constructs, aligning closely with findings from contemporary AI-enhanced education research. Adaptive Learning Technologies in this study achieved a Cronbach's alpha of 0.901 and AVE of 0.614, which is consistent with Zhao [44], who reported alpha values exceeding 0.88 when assessing adaptive platforms' effectiveness in improving mathematics and English achievement. Similarly, Digital Literacy displayed exceptionally high internal consistency (α = 0.953, AVE = 0.733), mirroring Yaseen et al. [11] who documented reliability coefficients above 0.95 in measuring digital competence within AI-supported learning environments.

The Interactive AI Tools construct also demonstrated excellent reliability (α = 0.955, AVE = 0.748), which is consistent with Ebrahimi et al. [43] who reported similar high factor loadings (>0.70) and satisfactory reliability (>0.90) in evaluating intelligent tutoring systems. These results collectively affirm that AI-based educational tools are measured with strong psychometric properties, ensuring accurate construct representation. Furthermore, the Student Skills in this study showed an alpha of 0.871 and an AVE of 0.711. These results align with what Zhang [45] found when measuring competencies developed through active and adaptive learning environments. Overall, these findings are in line with prior research, emphasizing that adaptive technologies, interactive AI tools, and digital literacy can be reliably and validly measured. Such convergence across studies strengthens confidence in applying this measurement model to higher education settings, particularly within AI-driven learning contexts in Bahrain and other GCC countries.

Table 1.
Outer Loadings, Convergent Validity, and Measurement Model Assessment.

Items	Outer loading	Cronbach's Alpha	CR	(AVE)
ALT1	0.507			
ALT2	0.855			
ALT3	0.845			
ALT4	0.879	0.901	0.899	0.614
ALT5	0.855			
ALT6	0.690			
DL1	0.982			
DL2	0.853			
DL3	0.837			
DL4	0.848			
DL5	0.967	0.953	0.955	0.733
DL6	0.800			
DL7	0.632			
DL8	0.882			
IAT1	0.897			
IAT2	0.899			
IAT3	0.932			
IAT4	0.900	0.955	0.952	0.748
IAT5	0.758			
IAT6	0.761			
IAT7	0.890			
SS1	0.886			
SS2	0.952			
SS3	0.982	0.871	0.868	0.711
SS4	0.946			
SS5	0.064			

Note: * Adaptive Learning Technologies (ALT) and Interactive AI Tools, Usman et al. [46], Digital Literacy Patrinos et al. [47], Student Skills.

4.1. R-Square

The model has significant explanatory power: Student Skills has an R^2 value of 0.733, indicating that the proposed variables explain 73.3% of the variation in student abilities. This exceeds the commonly cited criterion of 0.50 for strong prediction models Yalçin [48] and shows substantial model dependability. Similar investigations in AI-enhanced education indicated comparable predictive powers, with R^2 values between 0.65 and 0.71 [49, 50], highlighting the model's alignment with current research. The observed R^2 here underscores that the integrated framework proficiently encapsulates the determinants affecting skill development in higher education, especially in private institutions in Bahrain.

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Table 2.
Coefficient of Determination Result R^2.

Endogenous Variable	R-square	Impact size
SS	0.733	High

Source: Adaptive Learning Technologies, Interactive AI Tools, Digital Literacy, and Student Skills.

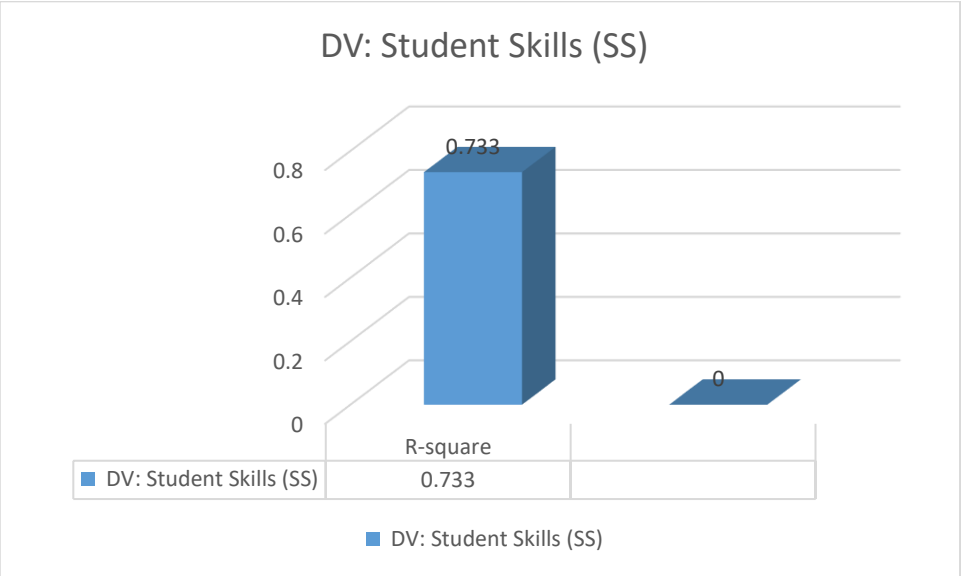

Figure 2.
R^2.

4.2. Structural Model

The structural model results demonstrate that Interactive AI Tools ($\beta = 0.523$), Adaptive Learning Technologies ($\beta = 0.179$), and Digital Literacy ($\beta = 0.160$) have a positive effect on Student Skills, accounting for 73.3% of the variance ($R^2 = 0.733$). Factor loadings were strong (all > 0.75), affirming the model's dependability and validity in augmenting student skills.

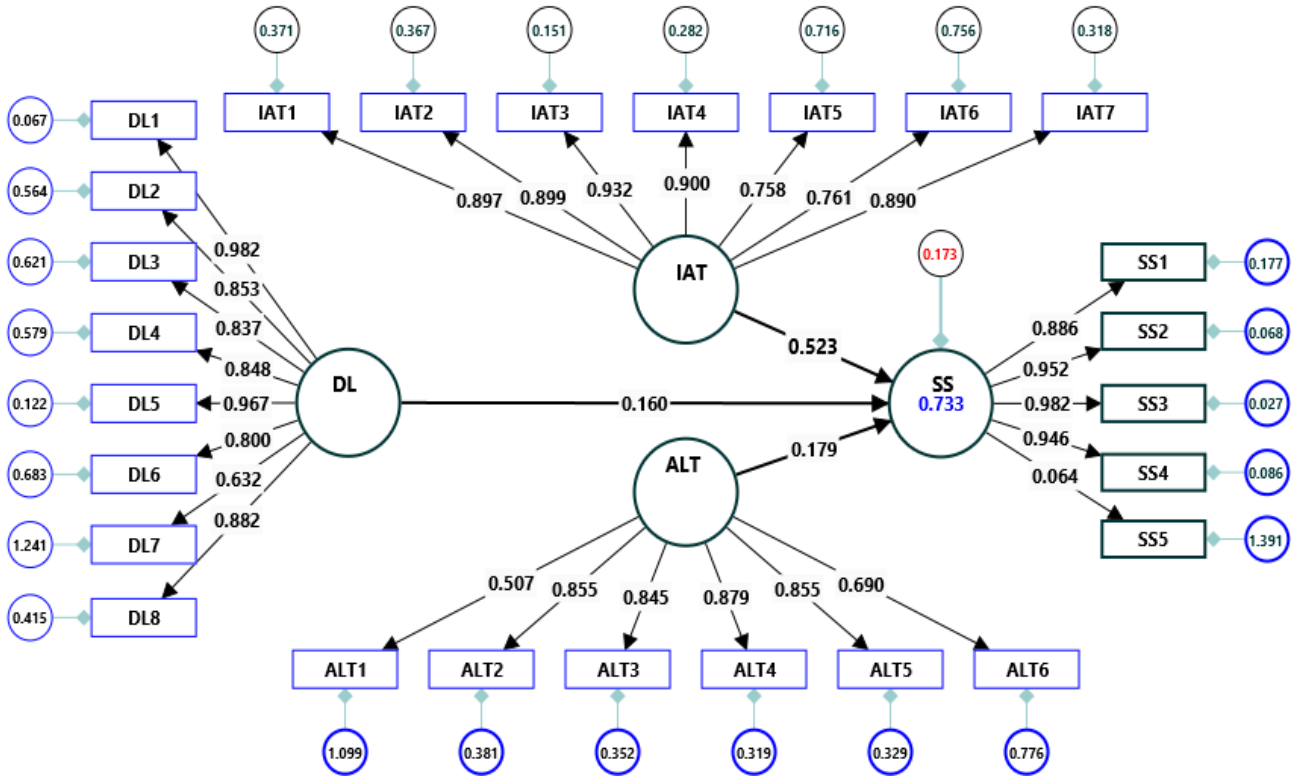

Figure 3.
Structural Model.
Note: Adaptive Learning Technologies and Interactive AI Tools, Digital Literacy, and Student Skills

4.3. Standardized Factor Loadings

The standardized factor loadings in the matrix above indicate that all structures display significant indicator reliability, with the majority of loadings above the suggested threshold of 0.70 [51]. Adaptive Learning Technologies loadings vary from 0.507 to 0.879, aligning with Ramírez et al. [52] who documented loadings above 0.50 for educational adaptive platforms. Digital Literacy indicators show notably high loadings (0.632–0.982), and this was consistent with previous findings. Falkner [53] underscored the need for precise evaluation of digital competences in AI-augmented learning contexts. Interactive AI Tools reported by Usman et al. [46] showed commendable dependability (0.758–0.932): similar to the findings of Chen and Zou [54] who evidenced robust factor loadings for intelligent teaching systems. The loadings of Student Skills items range from 0.886 to 0.982, affirming the construct's validity, consistent with the findings of Johnsson et al. [55] who noted comparable reliability in skill-based evaluations. These findings provide evidence that the measurement approach is psychometrically reliable and aligns with current AI-driven educational research.

Table 3.
Standardized Factor Loadings.

Items	ALT	DL	IAT	SS
ALT1	0.507			
ALT2	0.855			
ALT3	0.845			
ALT4	0.879			
ALT5	0.855			
ALT6	0.690			
DL1		0.982		
DL2		0.853		
DL3		0.837		
DL4		0.848		
DL5		0.967		
DL6		0.800		
DL7		0.632		
DL8		0.882		
IAT1			0.897	
IAT2			0.899	
IAT3			0.932	
IAT4			0.900	
IAT5			0.758	
IAT6			0.761	
IAT7			0.890	
SS1				0.886
SS2				0.952
SS3				0.982
SS4				0.946
SS5				0.064

Note: Adaptive Learning Technologies, Interactive AI Tools, Digital Literacy, and Student Skills.

4.4. The Assessment of the Inner Model and Hypotheses Testing Procedures

The findings in Table 4 indicate that all proposed relationships are statistically significant, highlighting the beneficial impact of Adaptive Learning Technologies, Digital Literacy, and Interactive AI Tools on student skills. The path coefficient for ALT → SS is 0.179 ($t = 3.955$, $p < 0.001$), indicating a small but significant impact of adaptive technology on improving student skills. This corresponds with the findings of Rosli and Abdullah [56], who also documented substantial learning improvements using adaptive systems in mathematics and English instruction. The correlation between digital literacy and student performance was found to be significant ($\beta = 0.160$, $t = 3.421$, $p < 0.001$), highlighting the essential function of digital literacy in enhancing student outcomes. The results align with Chen [57] who demonstrated that students with enhanced digital capabilities attained better learning outcomes when using AI-assisted educational platforms. The greatest significant influence was of the IAT → SS, with a coefficient of 0.523 ($t = 6.510$, $p < 0.001$), underscoring interactive AI technologies as the primary predictor. This aligns with Bhijakkanarin and Kenaphoom [58] the discovery that intelligent teaching systems significantly enhance problem-solving and analytical reasoning abilities. The findings together justify all three hypotheses and reinforce previous research indicating that AI-driven instructional tools, when accompanied by digital literacy, substantially improve student abilities in higher education.

Table 4.
Mean, STDEV, T values, P values, Decision.

Construct	Original sample (O)	Sample mean (M)	Standard deviation (STDEV)	T statistics (|O/STDEV|)	P values
ALT → SS	0.179	0.178	0.045	3.955	0.000
DL → SS	0.160	0.161	0.047	3.421	0.000
IAT →SS	0.523	0.520	0.080	6.510	0.000

Note: Adaptive Learning Technologies, Interactive AI Tools, Digital Literacy, and Student Skills.

5. Discussions

This research empirically confirms the direct impacts of Adaptive Learning Technologies, Interactive AI Tools, and Digital Literacy on student skills at private educational institutions in Bahrain. The results not only conform to existing research but also enhance the importance of AI-enabled education in the Gulf region, presenting substantial implications

for educational philosophy, technological integration, and instructional methodology. In what follows, the study's hypotheses will be tested and discussed.

H_1: Adaptive Learning Technologies → Student Skills

The findings indicate that ALT has a significant and positive effect on SS ($\beta = 0.179$, $p < 0.001$). This supports the work of Wan and Wan [59], who revealed that adaptive platforms, specifically the Yixue system, significantly improved student performance in mathematics and language disciplines by customizing learning pathways to individual requirements. Likewise Kantathanawat et al. [60] noted that adaptive tools resulted in gradual enhancements in conceptual understanding and problem-solving skills in higher education courses.

The modest path coefficient in this research indicates that, while customization enhances learning outcomes, its effectiveness may be limited by contextual variables such as the availability of localized information, teacher preparedness, and students' previous experience with adaptive systems. In Bahrain, where the implementation of adaptive learning is still nascent, the full educational potential of these technologies may not yet be fully realized. This conclusion aligns with Nyathi and Sisimayi [61] who contend that adaptive learning requires a comprehensive instructional redesign to achieve significant improvements in competencies such as critical thinking and technology-based problem-solving.

H_2: Interactive AI Tools → Student Skills

The IAT tools had the most significant effect on SS ($\beta = 0.523$, $p < 0.001$), making it the most influential predictor in the model. This is consistent with the findings of Na-songkhla et al. [62] and Liu et al. [63] which indicates that intelligent tutoring systems and conversational agents significantly improve analytical thinking, cognitive flexibility, and engagement. Interactive AI solutions provide a dialogic learning environment by offering real-time scaffolding, adaptive questioning, and individualized feedback, which together enhance conceptual comprehension.

This study theoretically corroborates constructivist and social learning theories, which highlight active engagement and collaborative knowledge production as essential factors in skill development [64]. The findings indicate that in Bahrain's higher education environment, where students are progressively engaged with digital platforms and interactive AI solutions, interactive AI tools may be more impactful than static or merely adaptive content. This profound connection facilitates bridging the gaps in analytical thinking and improves the capacity to apply information in intricate, technology-driven contexts.

H_3: Digital Literacy → Student Skills

Digital literacy had a substantial, beneficial impact on SS ($\beta = 0.160$, $p < 0.001$), underscoring its essential role in AI-enhanced education. This finding aligns with the results of Abdelmagid et al. [65], who discovered that students with advanced digital skills are more proficient in using AI platforms, leading to improved learning outcomes.

In the Bahraini context, this is especially significant: despite the advanced digital infrastructure, there exists heterogeneity in students' digital literacy. The high DL levels empower students to use adaptive platforms more effectively, critically evaluate material from AI instructors, and employ digital skills in problem-solving and analytical activities. This result underscores that digital literacy serves as a catalyst, enhancing the educational advantages of both ALT and IAT. In the absence of sufficient digital literacy, the transformational potential of artificial intelligence in education may remain inadequately leveraged.

This research demonstrates that the integration of AI technologies and comprehensive digital literacy programs accounts for 73.3% of the variation in student skills ($R^2 = 0.733$), showing compelling evidence of its potential to enhance 21st-century capabilities in higher education. These results not only correspond with worldwide studies but also address a regional research need, implying that Bahraini institutions are poised to use AI technologies to enhance student learning outcomes.

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5.1. Regional Insights: Bahrain and GCC Context

Despite Bahrain's advanced digital infrastructure and progressive AI-driven educational initiatives, there is a paucity of empirical research on the interplay of ALT, IAT, DL, and SS. Previous regional studies have mostly focused on technology adoption Jain et al. [66] or innovation initiatives, without quantitative proof of AI's influence on student competencies.

This study addresses the gap by demonstrating that the model has substantial explanatory power ($R^2 = 0.733$), marking it as one of the first empirical validations of AI-driven educational advantages in the Bahraini higher education sector.

The results align with other research conducted in the GCC region. According to Singh et al. [67], structured intelligent learning assistants in Saudi Arabia enhance creativity and academic achievement; however, their strict regulations may hinder student independence. The minimal ALT coefficient in this study suggests a similar trend, indicating that highly structured customization may not fully promote the enhancement of critical thinking and creative skills without additional interactive resources.

5.2. Implications for Theory and Practice

The study's findings confirm that the integration of ALT and IAT in higher education, bolstered by sufficient DL, significantly enhances students' performance, problem-solving abilities, and critical thinking skills. The substantial impact of IAT highlights the need for educational institutions to pursue interactive, conversational AI systems that can engage students effectively. This result corroborates constructivist learning theories Al Nabhani et al. [68], highlighting that dialogic, active learning settings foster cognitive growth more efficiently than passive, adaptive systems alone.

These discoveries possess strategic significance for Bahrain and the GCC countries, where the deployment of AI is rapidly advancing. Policymakers must prioritize concurrent expenditures in digital literacy training to guarantee equal advantages from AI-driven schooling. Universities must develop a curriculum that includes interactive AI solutions in conjunction with adaptive platforms to establish a balanced, skill-enhancing educational environment.

5.3. Limitations and Future Research

While the model has significant explanatory power, its generalizability is enhanced since the study sample was drawn from a number of private colleges rather than public institutions in Bahrain. Although this extensive sample enhances representativeness, further study might augment external validity by including other institutions from various GCC nations. Implementing a multi-university and cross-national research framework will provide more comprehensive comparative assessments, highlighting institutional and cultural differences in AI adoption. Furthermore, using mixed-method techniques and longitudinal designs would provide more profound insights into behavioral interactions with AI-driven technology and demonstrate more robust causal linkages among adaptive learning tools, digital literacy, and student skill development.

6. Conclusion

This study enriches the empirical literature on AI-enhanced education in Bahrain by demonstrating that interactive AI tools, adaptive learning platforms, and digital literacy significantly influence the development of student skills. This research emphasizes the transformative potential of AI in education, aligning with global results and offering area-specific insights, and providing practical advice for policymakers and educators in the GCC region.

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