Comparison of Three Traditional, Online, and Blended Learning Methods in Teaching Physics of Electricity & Magnetism: A Look at Experience of Iran's Higher Education System in Corona and Post-Corona Periods

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A R T I C L E I N F O	A B S T R A C T
   K E Y W O R D S 	The aim of this study is to compare three teaching-learning methods traditional, online, and blended in the instruction of the Physics of Electricity and Magnetism course. The research method is quantitative and comparative in nature. The population and sample consist of engineering students from the Faculty of Engineering at the University of Tehran who were enrolled in the Physics of Electricity and Magnetism course. The sampling method was convenience sampling (n = 401). Data collection was conducted through the E-Learn and Golestan platforms, and data analysis was performed using analysis of variance (ANOVA) with SPSS version 24. The findings indicated that the ANOVA test rejected the null hypothesis of equal means among the three instructional methods, with a significance level (sig) less than 0.05. Also, there is a statistically significant difference in academic achievement between the traditional and blended learning methods. Furthermore, Welch and Brown-Forsythe tests confirmed significant differences among the mean scores of the three learning methods. Accordingly, the students' grades and academic results demonstrate that student performance under the blended learning method is superior to the other two methods. Based on the Iranian experience, it is recommended that instructors of this course in universities of developing countries adopt the blended learning approach in their teaching process.

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1. Introduction

The contemporary world is constantly undergoing various transformations. Consequently, in order to adapt to these changes, there is a growing need to evaluate new teaching methods within the teaching-learning process. This evaluation supports the adaptation and evolution of instructional approaches to better align with students' needs. In fact, enhancing interactive and engaging teaching strategies in the classroom contributes significantly to increased student participation and motivation (Liu et al., 2016). Moreover, the transformation of teaching methods is essential for fostering critical thinking, problem-solving, and communication skills. In addition, modern teaching approaches contribute to cultivating a culture of innovation, creativity, and collaboration among students, educators, and the broader academic community (Liu et al., 2016; Szőköl et al., 2023). Traditional learning refers to conventional instructional methods that have been employed over an extended period. It is characterized by face-to-face interaction, a structured curriculum, prescribed textbooks, and conventional assignments and assessments (Yi et al., 2021; Mirmoghtadaie et al., 2019; Kim & Jung, 2019). However, traditional learning also faces limitations, such as a lack of flexibility in terms of time and place, and high infrastructural costs (Karbasi et al., 2023). Online learning possesses several key features, including: 1. It allows students to access learning materials and participate in educational activities at their own pace and convenience, unconstrained by physical location or fixed schedules. 2.It offers a wide range of learning resources such as multimedia content, interactive simulations, discussion forums, and virtual classrooms, catering to diverse learning styles and preferences (Nicol et al., 2003; Yin et al., 2023). 3. It utilizes adaptive algorithms capable of adjusting content and learning pace based on students' performance and progress, thus delivering personalized learning experiences (He et al., 2021; Gupta et al., 2018). 4. It facilitates collaboration among students through discussion boards, group projects, and virtual study groups, enabling peer-to-peer learning and the development of teamwork skills (Abdurrahmansyah et al., 2022; Nicol et al., 2003). 5. It provides opportunities such as automated assessments, peer review, and instructor feedback, allowing for continuous evaluation and improvement throughout the learning process (Abdurrahmansyah et al., 2022; Yin et al., 2023). 6. It enhances access to education for students with disabilities, those living in remote areas, or those with scheduling constraints facilitate learning and promote inclusivity and equal learning opportunities (Abdurrahmansyah et al., 2022; Nicol et al., 2003). 7. Online learning can also support lifelong learning and professional development by offering a wide array of courses and certifications that are accessible at various stages of an individual's career development (Nicol et

al., 2003; Yin et al., 2023). These features underscore the flexibility, personalization, collaboration, and accessibility afforded by online learning, making it an increasingly popular choice among students. However, challenges such as reduced social interaction, the need for advanced digital literacy, and reliable internet access are considered notable limitations of this method (Alessa et al., 2023). Blended learning is characterized by its unique integration of traditional and online instructional methods. It emphasizes student engagement, learner segmentation based on behavior, the influence of student characteristics and digital literacy on academic performance, and the necessity of adaptive teaching strategies in learning environments. Blended learning combines conventional face-to-face instruction with elements of online learning, offering a mix of educational materials and activities through virtual platforms. Studies have shown that students who demonstrate higher levels of engagement in online components are more likely to achieve better academic outcomes. This indicates a positive correlation between engagement and academic performance in blended learning environments (Cao, 2023; Darlis & Sari, 2021; Runling & Aiguo, 2023; Yin et al., 2023). The effectiveness of blended learning is influenced by students' characteristics and their level of digital literacy. However, the impact of these factors on academic performance may vary; some studies have reported negligible effects on learning outcomes (Darlis & Sari, 2021).According to Mintii (2023), instructional approaches in blended environments include:

- The use of interactive and multimedia content—such as videos and simulations—to enhance student engagement and interest in instructional materials.
- Adaptation to student needs and the provision of personalized feedback to improve learning outcomes.
- Enhanced collaboration among students in both face-to-face and online settings, fostering communication, interaction, and teamwork skills.
- Applicability for teaching a wide range of subjects and academic levels. Nonetheless, the need for high technical skills and effective coordination between online and in-person components remain as limitations of the blended approach.

The COVID-19 pandemic significantly influenced the expansion and adoption of new instructional methods across educational systems worldwide. In response to social distancing requirements aimed at preventing the spread of the virus, universities rapidly transitioned from traditional education to online and blended learning modalities (Krishnan et al., 2020; Lemay et al., 2021). This shift became necessary due to widespread closures and was essential in preventing further transmission of the virus, ultimately resulting in the broad acceptance of remote learning methods. The transition to online education affected both faculty and students in terms of their

readiness to participate in learning activities, as well as their personal development, academic performance, collaboration, and spiritual well-being (Setiadi et al., 2023; Parmin et al., 2020). The COVID-19 pandemic led to the implementation of emergency remote teaching and revealed new challenges and strategies for learning. Universities were compelled to redesign and adjust their teaching methods, transitioning from "on-site education" to "remote learning" in order to adapt to the new educational environment imposed by the COVID-19 pandemic (Chiyón et al., 2021). The closure of universities and the shift to online learning disrupted traditional teaching practices and presented challenges for students, including the need for high-speed internet, access to electronic devices, and the setup of new learning environments suitable for engaging with online coursework. At the same time, students faced both technical and physical barriers, while demands for self-discipline and time management skills also affected their mental health and motivation to learn (Gao, 2020). The integration of computer technologies and the rapid development of digital competencies among students and faculty accelerated the adoption of blended learning in higher education. Under these circumstances, the importance of digital transformation and the advantages of blended learning models during the pandemic became evident, acting as a catalyst for the widespread acceptance of new instructional methods. The expansion of online and blended education has brought about significant changes in teaching approaches and emphasized the importance of flexibility, adaptability, and the integration of online learning tools within the educational landscape (Finlay et al., 2023).

In Iran, according to a report by (ISNA News Agency, 2016), the Ministry of Science, Research, and Technology oversees 2,640 universities and 5,000 different academic programs. During the COVID-19 pandemic, all universities were compelled to shift from traditional in-person education to online learning. The University of Tehran was no exception and adopted online and remote learning methods. Before the pandemic, the learning process at the University of Tehran—as the first modern university in Iran—was primarily conducted through traditional face-to-face instruction. From the second semester of the 2019–2020 academic year to the first semester of 2022–2023, online and blended learning were implemented over four consecutive semesters using the e-Learn educational management platform. Additionally, during the first semester of 2022–2023, physics courses were taught using a blended format consisting of 40% online and 60% face-to-face instruction (Digital Technologies Deputy of University of Tehran, 2022). The intermittent closures and reopenings of universities during the COVID-19 and post-COVID periods led the present researcher to question whether there were actual differences among these instructional methods. The purpose of this study is to compare the effectiveness of three learning methods

traditional, online, and blended on the academic performance of undergraduate engineering students in the course "Electricity and Magnetism" (hereafter referred to as the physics course). At the University of Tehran, traditional learning was delivered through in-person, face-to-face classroom instruction. Online learning was conducted via the web-based educational management system of the University of Tehran. Blended learning comprised both online and in-person components: the online portion included instructional videos and synchronous virtual classes hosted on the university's educational platform, while the in-person portion involved face-to-face sessions held in traditional classroom settings.

2. Literature Review

In recent years, numerous studies have been conducted on the differences between teaching methods. These investigations suggest that each instructional approach possesses unique advantages and limitations, and their effectiveness depends on various factors such as student preferences, course content, and learning objectives (Jia et al., 2024; Rusdi et al., 2023). Traditional learning facilitates direct interaction between students and instructors, enables immediate feedback, and fosters a sense of community. However, this approach may lack flexibility and might not address the needs of students who prefer self-paced or remote learning (Sendra-Pons et al., 2022). Online learning, which utilizes digital platforms and software, has gained popularity in recent years, particularly in the aftermath of the COVID-19 pandemic. This mode of teaching and learning offers flexibility, accessibility, and the capacity to reach a broader audience (Ramadhani et al., 2023; Sendra-Pons et al., 2022). Furthermore, it may be more cost-effective and environmentally sustainable by reducing the need for physical infrastructure and transportation (Sendra-Pons et al., 2022). Nevertheless, online learning may lack the personal interaction and hands-on experiences provided by traditional education (Sendra-Pons et al., 2022). Fatima et al., (2022) found that while online learning provides benefits such as easier task management and timely feedback, students still tend to prefer traditional education due to its more conducive study environment and greater opportunities for interaction. Makarova (2021) reported a generally positive attitude toward online learning among students, though she noted challenges such as procrastination and a lack of focus. Meanwhile, Salameh (2023) emphasized the importance of well-designed instructional planning and effective integration of technology in online education. Blended learning integrates elements of both traditional and online education (Jia et al., 2024; Rusdi et al., 2023; Sendra-Pons et al., 2022). The goal of this approach is to leverage the strengths of both methods to promote flexibility, enhance motivation, and create a more engaging educational

experience (Rusdi et al., 2023; Sendra-Pons et al., 2022). Studies by Mohammad and Ramadhani have shown that blended learning is more effective than fully online learning, as a growing number of higher education institutions are adopting blended programs due to their potential benefits (Ramadhani et al., 2023).

A majority of researchers agree on the positive impact of utilizing educational technology in teaching. However, relatively few studies have demonstrated its direct effect on students' final grades. Romero (2021) found that traditional teaching methods often lead to a lack of motivation, engagement, and self-efficacy among students. Liu et al. (2016), through a systematic review of 56 eligible articles from various countries published in reputable databases[3] up to September 2014, analyzed the effectiveness of blended learning in the health domain. Their findings indicated that blended learning is more effective than non-blended methods in knowledge acquisition and has a greater positive impact. The study conducted by Mueller and Wulf (2022) highlighted two crucial factors flexibility and interaction in blended learning environments. They argued that these environments must consider the cognitive characteristics of learners. Further research suggests that blended learning can enhance student engagement, motivation, and learning outcomes (Jia et al., 2024; Rusdi et al., 2023). By integrating online games and other interactive elements, blended learning can stimulate active participation and improve academic performance (Rusdi et al., 2023). However, the success of blended learning methods depends largely on providing adequate tools and support for both students and instructors to effectively utilize online resources and technologies (Sendra-Pons et al., 2022; Jia et al., 2024). It also allows instructors to better address the diverse needs of students who vary in learning styles and abilities (Cetin et al., 2004; Szőköl et al., 2023). The COVID-19 pandemic emerged as both a challenge and an opportunity for educational systems (Daniel, 2020). Universities and educational institutions were closed to reduce and control the spread of the virus, disrupting traditional education and forcing instructors to adopt online learning methods. Consequently, most universities around the world were compelled to reconsider their teaching and assessment strategies (Daniel, 2020; Lemay et al., 2021; Pokhrel & Chhetri, 2021). A comparative study conducted by Müller in 2022 at the University of Zurich examined traditional, online, and blended learning approaches. The findings indicated that reducing face-to-face classroom time by 30 to 79 percent did not significantly affect learning outcomes. Blended learning produced results that were largely equivalent to those of traditional instruction. Furthermore, Müller demonstrated that the differences between blended and traditional learning environments are minimal and that blended formats are not associated with poorer learning

outcomes they are, in fact, comparable to conventional classroom education. The reduction in classroom time may also contribute to lowering educational costs. This study encouraged higher education institutions to offer students greater flexibility in terms of time and location within their academic programs (Müller & Mildenberger, 2021).

In Iran, several studies have also investigated the effects of various teaching and learning methods. For instance, Eslami et al (2018) showed that students at Jundi Shapur University expressed a high level of satisfaction with Teaching has a significant impact on students' academic success. The results revealed that over 61% of students were generally more satisfied with online education compared to traditional teaching methods. The findings of Mahdizadeh (2023) on the effectiveness of blended education showed that the academic performance of students in the experimental group significantly improved in subjects such as Iranian painting and the design of functional objects. Ranjbarfard and Zandvakili (2021) found that using a combination of diverse instructional methods—including training with specialized software and particularly game-based learning alongside traditional instruction—was beneficial. This combination led to increased student satisfaction, learning, motivation, capability, engagement, and enjoyment. Asfijani (2018) reported that although blended learning did not have a statistically significant impact on the final exam scores of undergraduate students in the field of educational sciences at the University of Isfahan, it did have a significant and positive effect on their level of satisfaction. Similarly, Karimi et al. (2022) demonstrated the greater effectiveness of blended learning compared to traditional methods in developing clinical care planning. The findings of Rajabian et al. (2022) also indicated that blended learning had a significant impact on self-concept, academic enthusiasm, and its components among second-grade elementary students in Gorgan, leading to enhanced self-concept and academic motivation. In summary, the findings from empirical research on the performance of different instructional methods appear to be contradictory (Priluck, 2004; Wiechowski & Washburn, 2014), and the conditions under which blended learning can enhance learning outcomes remain unclear (Mueller & Wulf, 2022).

3. Research Method

This study adopts a quantitative comparative research design, aiming to compare three instructional methods traditional, online, and blended learning—in the teaching of physics. The statistical population consists of all engineering students at the Faculty of Engineering, University of Tehran. The sample was selected through convenience sampling, including all students who participated in the final exam (n = 401). Data collection was conducted through field methods, and

the primary data source was students' final exam scores in the physics course. The data were gathered over a three-year period (from 2019 to 2022), retrieved from the University of Tehran's Golestan and E-Learn platforms. In each of the three years, and across all three teaching methods (face-to-face, online, and blended), the instructor remained the same. Additionally, the educational resources, physics course syllabus, and difficulty level of the exam questions were kept consistent. Each instructional method was applied for one academic semester (16 weeks) during the three-year period. The physics course, which combines theoretical and laboratory components, was selected due to its simultaneous emphasis on conceptual understanding and computational reasoning. This study is the result of a three-year investigation into these three instructional approaches. The three instructional approaches examined in this study are traditional, online, and blended learning. Each of these methods possesses distinct characteristics, shaped by the nature of the educational platform used. Consequently, for each approach, a specifically tailored course design must be developed and implemented in alignment with its learning modality. In the traditional learning approach, the presence and interaction between the instructor and students occurred exclusively within the physical classroom and relied primarily on the use of printed textbooks. Teaching and learning were conducted through face-to-face sessions, with minimal integration of digital tools or resources. The online learning method was implemented through a web-based learning management system (LMS). In this mode, instructors utilized various e-learning tools to facilitate the teaching-learning process. These included educational videos, synchronous and asynchronous virtual classes, assignments and quizzes, as well as access to digital versions of reference books available on the university's E-Learn platform. In addition, to enhance communication and engagement with students, instructors also used social media platforms. The blended learning approach combined elements of both traditional and online learning. In this model, both instructors and students had access to a wide range of e-learning resources available on the Moodle-based ILearn system, alongside physical textbooks, in-person classroom sessions, and social media tools. The instructional activities under the blended learning format included in-person classes, synchronous and asynchronous virtual sessions, instructional videos, assignments, assessments, and social media interactions. In this approach, 40% of the instruction was delivered online, while the remaining 60% took place through traditional face-to-face methods.

Table 1: Course Plan for the Three Learning Methods

Learning method	Online classes	Films	Assign-ments	Main exams	Social network	Face-to-face course sessions	Place of activity	Number of students	Academic year (second semester)
Traditional	-	-	8	2	-	28	classrooms	137	2019-20
Online	20	16	9	4	Yes	-	www.elearn.ut.ac.ir	153	2020-21
Blended	8	16	10	2	Yes	18	www.elearn.ut.ac.ir, and classrooms	111	2021-22

Data were analyzed using Analysis of Variance (ANOVA) with IBM SPSS Statistics version 24.

4. Findings

Research Question 1 – In which learning method (traditional, online, or blended) is students' academic achievement higher? Table 2 presents descriptive statistics, including the mean, minimum and maximum values, standard deviation, and the 95% confidence interval for the dependent variable, broken down by the three learning methods. In this study, the learning methods (traditional, online, and blended) are the independent variables, while academic performance (final exam scores) serves as the dependent variable. The mean score for traditional learning is 13.6, for online learning it is 14.68, and for blended learning it is 15.01. The difference between the means clearly reflects the relative performance outcomes associated with each learning method.

Table 2: Descriptive Statistics of the Three Learning Methods – Traditional, Online, and Blended

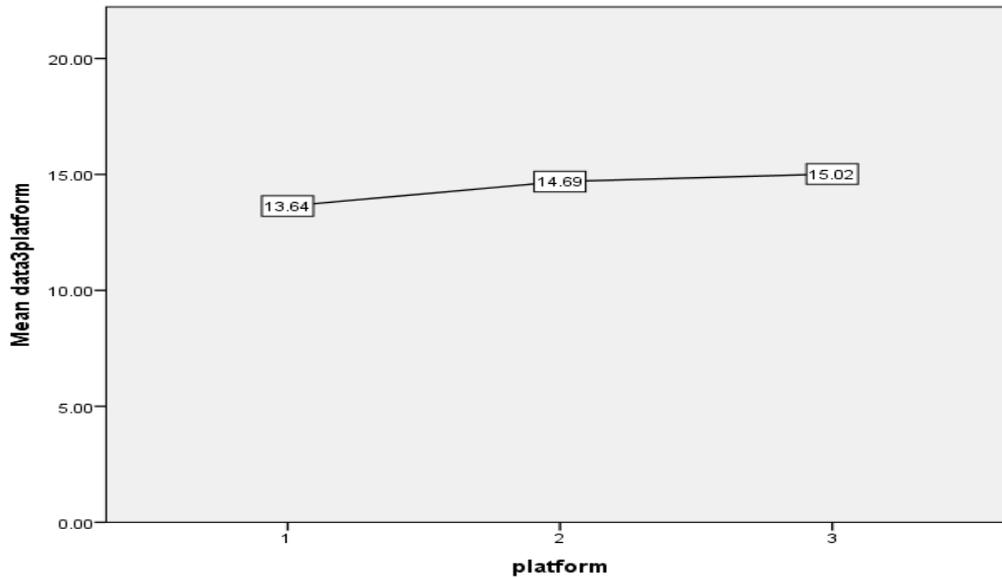| Learning Method	N	Mean	Standard Deviation (SD)	Minimum	Maximum
Traditional Learning	137	13.64	3.42	8	20
Online Learning	153	14.69	2.75	9	20
Blended Learning	111	15.02	4.11	9.5	20
Total	401	14.42	3.44	8	20

Figure 1. Line chart of academic achievement across the three learning methods: Traditional, Online, and Blended

In Figure 1, the superiority of the blended learning method compared to the other two approaches is clearly evident. The level of academic achievement in the teaching-learning process of the physics course is higher in the blended learning method than in both the traditional and online methods. In the ANOVA test, the null hypothesis stating the equality of means among the three learning methods is rejected. The significance value is sig = 0.003, which is less than 0.05, indicating that there is a statistically significant difference in academic performance between at least two of the learning methods. Welch's and Brown-Forsythe tests also confirm significant differences in the means across the three learning approaches. Table 3 presents the skewness and kurtosis values, which fall within the acceptable range of -2 to +2, indicating that the data distribution is approximately normal.

Table 3: Descriptive Statistics of Academic Performance Across Three Learning Methods

Variable	N	Minimum	Maximum	Mean	Std. Deviation	Skewness	Std. Error (Skewness)	Kurtosis	Std. Error (Kurtosis)
data3platform	401	8.00	20.00	14.42	3.45	-0.023	0.122	-1.201	0.243
Valid N (listwise)	401								

Table 4 presents the results of the Welch and Brown-Forsythe tests to examine the equality of means across the three learning methods (traditional, online, and blended). The results indicate a statistically significant difference between the means, as the significance value (Sig.) in both tests is 0.005, which is less than the standard threshold of 0.05.

Table 4: Welch and Brown-Forsythe Tests for Equality of Means

Test	Statistic	df1	df2	Sig.
Welch	5.461	2	236.105	0.005
Brown-Forsythe	5.454	2	312.436	0.005

Question 2: Which learning method should be selected for teaching the course of Electricity and Magnetism?

To answer Question 2 and to analyze and compare multiple means, ANOVA and post-hoc tests were used in the analysis of variance. According to the significance level of the post-hoc LSD test in the analysis of variance, there is a significant difference between the traditional learning method and the online and blended learning methods. However, no significant difference is observed between the online and blended learning methods.

Table 5: LSD Post-Hoc Test in the Analysis of Variance

Post Hoc Tests	Multiple Comparisons	Dependent Variable: data3platform			95% Confidence Interval	
(I) platform	(J) platform	Mean Difference (I-J)	Std. Error	Sig.	Lower Bound	Upper Bound
Traditional	Online	-1.05268*	.40054	.009	-1.8401	-.2652
	Blended	-1.37945*	.43486	.002	-2.2344	-.5245
Online	Traditional	1.05268*	.40054	.009	.2652	1.8401
	Blended	-.32676	.42457	.442	-1.1614	.5079
Blended	Traditional	1.37945*	.43486	.002	.5245	2.2344
	Online	.32676	.42457	.442	-.5079	1.1614

*.The mean difference is significant at the 0.05 level.

Table 5, the LSD post-hoc test, shows that there is a significant difference between the learning methods (traditional, online, and blended), with the blended learning method demonstrating better performance compared to the other two learning methods.

Table 6: ANOVA Test

ANOVA data3platform Sum of Squares	df	Mean Square	F	Sig.
Between Groups	134.608	2	67.304	5.804
Within Groups	4615.122	398	11.596	
Total	4749.730	400		

The ANOVA test shows a significant difference between the mean scores of the physics course across the three learning methods.

5. Conclusion

The comparative study of traditional, online, and blended learning methods in recent years, particularly in response to the COVID-19 pandemic, has gained significant attention from researchers worldwide. The first finding of the research regarding academic progress across the three learning methods in the physics course shows that blended learning outperforms the other two methods. Students have demonstrated better performance in the blended learning method compared to traditional and online learning methods. Therefore, the blended learning method is recommended over traditional and online methods. This finding aligns with studies by Yu et al. (2022), Liu et al. (2016), and Vallée et al. (2020). The second finding addresses which learning method should be chosen for teaching the course on Electricity and Magnetism. Based on the results presented in Table 6, blended learning is the preferred method. This result supports the findings of Elgohary et al. (2022), Yin et al. (2023), Chiu (2021), Darlis & Sari (2021), Runling & Aiguo (2023), and Cao (2023). Many studies indicate the positive effects of blended learning on learning outcomes, while others either do not observe significant differences between blended learning and traditional lectures or suggest that learners prefer face-to-face interactions (Mueller & Wulf, 2022). The conflicting findings suggest that the differences in the effects of blended learning methods may be due to variations in course design, technology quality, and face-to-face support. It appears that further investigation into additional indicators is needed to clarify these reasons.

This study provides strong evidence that blended learning outperforms both traditional and online learning in education, particularly in terms of knowledge acquisition. Key to the success of blended learning over the other two methods is the simultaneous use of online resources and face-to-face classroom instruction, which complement each other's weaknesses. The details of the lesson plan provided in Table 1 demonstrate the effective use of these resources and tools in the teaching and learning process. Educational videos can be a valuable tool for enhancing students' learning outcomes, especially when used alongside other teaching methods. The effectiveness of each method can be attributed to its ability to capture students' attention, address different learning styles, and present complex information in a more digestible format (Guellai et al., 2022; Guerra et al., 2017; Syahrozi, 2018). Therefore, it is suggested that particular attention be paid to the use of two key and valuable online teaching resources videos and assignments in blended learning and lesson plans. The effects of blended learning on education are complex and depend on various factors, including the quality of implementation, students' access to technology, and faculty support. While blended learning offers many advantages, such as personalized learning and increased interaction, it also presents challenges such as technological limitations and the need for significant infrastructural investment. The findings of this study support the idea that blended learning can be a more effective approach compared to traditional or online-only learning. Based on the research conducted in Iran, it is recommended that higher education systems in developing countries adopt blended learning methods in their teaching.

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