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E-Learning Adoption: Designing a Network-Based Educational and Methodological Course on *"Humans and Their Health"*

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Abstract

This study aims to explore the factors influencing the adoption of e-learning platforms in biology education and examine the impact of online learning on students' performance. This study investigates the relationships between perceived usefulness, perceived ease of use, attitude toward e-learning, flexibility, content quality, and students' behavioral intention to adopt e-learning activities. A mixed-methods approach was employed consisting of two phases: a questionnaire survey with structural equation modeling (SEM) to analyze data and an experiment with an independent sample t-test to assess the impact of online learning on student performance. Findings disclosed that perceived usefulness, perceived ease of use, attitude toward e-learning, flexibility, and content quality positively impacted students' behavioral intention to adopt e-learning and their performance. This study contributes to the theoretical understanding of the factors influencing e-learning adoption in biology education. Practical recommendations are provided for educators, instructional designers, and policymakers to facilitate the implementation of e-learning platforms in biology education. These recommendations include promoting the perceived usefulness and ease of use of e-learning platforms, fostering a positive attitude toward e-learning, enhancing flexibility, ensuring high-quality content, providing training and support for educators, and considering the needs of students with disabilities.

Keywords:

E-learning; Online Learning; Biology Education; Adoption; Perceived Usefulness; Content Quality; Perceived Ease of Use; Correctional Institutions.

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1- Introduction

E-learning, short for "*electronic learning*", has emerged as a transformative force in education, revolutionizing the way knowledge is acquired and shared. With the rapid advancement of technology, e-learning has gained significant prominence as an alternative to traditional classroom settings. It is an educational approach that uses digital platforms to deliver instructional content, allowing learners to access information and interact with instructors and peers remotely [1]. The convenience, flexibility, and accessibility offered by e-learning have contributed to its increasing significance in education [2]. Students can engage in self-paced learning, access various resources, and collaborate with individuals from different geographical locations. E-learning opens up new possibilities for education, empowering learners to personalize their learning experiences and acquire knowledge beyond the boundaries of traditional classrooms.

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Distance learning programs have witnessed a surge in interest as educational institutions recognize the potential of technology to reach a broader audience. Advancements in digital tools and communication technologies have paved the way for effective remote learning experiences. This growing interest in using technology for distance learning is fueled by several factors. The ability to transcend physical barriers enables learners from remote areas, those with mobility constraints, or individuals with busy schedules to access quality education. In addition, technology facilitates real-time interactions, collaboration, and multimedia content delivery, enhancing the engagement and effectiveness of distance learning programs. Educational institutions are increasingly embracing technology-driven approaches to cater to the evolving needs and preferences of learners in the digital age.

Identifying the factors influencing students' intention to adopt e-learning is crucial for the development and implementation of effective online education strategies, as supported by the existing literature. Research studies have consistently emphasized the significance of understanding these factors to enhance the design and delivery of online educational programs. For example, Zhang et al. [3] emphasized that understanding these factors allows institutions to improve the design and implementation of e-learning systems for mandatory blended learning environments. Fauzi [4] also concluded that analyzing factors affecting e-learning adoption enables stakeholders to develop effective strategies and interventions to sustain educational activities during emergencies. Furthermore, Rahayu et al. [5] argued that identifying key determinants helps create personalized and engaging e-learning experiences, which increases student motivation and learning outcomes. Studies have consistently shown the need to examine factors such as perceived usefulness, ease of use, social influence, information quality, and system quality to uncover barriers and facilitators shaping students' intentions to adopt e-learning [6, 7].

Liaw et al. [8] argued that identifying the determinants of students' intention to adopt e-learning can assist educators in tailoring instructional methods, content delivery, and technological resources to better meet students' needs and preferences. Furthermore, Venkatesh et al. [9] highlighted the importance of considering factors such as perceived usefulness, ease of use, and attitude toward technology in designing e-learning interventions. Understanding these factors enables educators to create engaging and user-friendly online learning environments, which in turn increase students' motivation, engagement, and overall learning outcomes [10]. By uncovering the factors that influence students' intention to adopt e-learning, educators and policymakers can make informed decisions about technology integration, curriculum design, and instructional strategies, leading to more effective online education practices and improved student experiences [11–13]. Therefore, this study aims to identify the factors that affect students' intentions to adopt e-learning. Understanding these factors is crucial because it allows educators and policymakers to develop effective strategies for promoting and enhancing e-learning adoption. By examining the various elements that influence students' willingness to engage in e-learning, this study seeks to shed light on the barriers, facilitators, and individual characteristics that shape their intentions. By addressing this research problem, this study contributes to a broader understanding of e-learning adoption and provides valuable insights for educators and institutions seeking to optimize online learning experiences [14, 15].

Camara [16] primarily focused on the integration of Industrial Revolution 4.0 Skills into the Senior High School Biology curriculum in the Philippines, emphasizing curriculum alignment and skill integration. Similarly, Choe et al. [17] investigated various online lecture video styles and their effects on student engagement and satisfaction, concentrating on student preferences in online education. Meanwhile, Sadikin & Hamidah [18] primarily examined the implementation of online learning in biology education at Jambi University, particularly in response to the COVID-19 pandemic. Their focus is on infrastructure and its impact on students' active learning, thus offering a more context-specific perspective. Maldarelli et al. [19] studied the development of instructional videos for laboratory procedures and their influence on student learning. Schönborn & Anderson [20] investigated student perceptions of virtual biology labs in online introductory biology courses, primarily comparing them to face-to-face labs. Stuckey-Mickell & Stuckey-Danner [21] delve into student perceptions regarding virtual biology labs in online introductory biology courses, juxtaposing them with face-to-face labs. Finally, Wei & Woodin [22] discuss the integration of scientific research experiences into the biology curriculum, with an emphasis on undergraduate research. The literature examined here comprises diverse studies in the realm of biology education, each shedding light on particular aspects of the field. However, these articles collectively reveal a noticeable gap in the comprehensive exploration of the intricate factors that shape e-learning adoption patterns among high school students. While the provided articles touch on various facets of biology education, they do not directly delve into the multifaceted factors influencing e-learning adoption among high school students. In contrast, this study aims to bridge this gap by designing a network-based educational methodological framework tailored to the unique needs and dynamics of high school biology education. This framework promises to provide a holistic understanding of the challenges and opportunities that define e-learning adoption within this specific educational context, thereby addressing an unmet need in the existing literature.

This study has two specific objectives. Firstly, it aims to investigate the factors influencing students' intentions to adopt e-learning. Through surveys, interviews, and data analysis, this study examines variables such as technological infrastructure, perceived usefulness and ease of use, attitudes toward e-learning, learning preferences, and external factors that impact students' intentions to adopt e-learning. By comprehensively exploring these factors, this research

provides a deeper understanding of the complex dynamics that influence students' decision-making processes regarding e-learning adoption.

Secondly, the study seeks to develop and implement a networked educational and methodological platform for teaching biology. This platform will incorporate interactive whiteboards, video communication, and instant comment exchange, among other tools. It will provide various educational materials, such as interactive illustrations, tasks, animated illustrations, videos, and presentations, both during and outside scheduled classes. This study will evaluate the effectiveness of this platform in enhancing students' engagement, independent learning skills, and their ability to apply knowledge to problem-solving. Furthermore, the study will consider factors such as students' access to technology and the suitability of distance learning environments for students with disabilities. By developing and implementing this platform, this study aims to contribute to the advancement of e-learning practices in the field of biology education and provide valuable insights into the potential benefits of integrating technology into distance learning programs.

The network educational and methodological platform developed in this study has significant potential benefits for biology education. By incorporating interactive whiteboards, video communication, and instant comment exchange, among other tools, the platform offers an engaging and interactive learning environment. The provision of various educational materials, such as interactive illustrations, tasks, animated illustrations, videos, and presentations, facilitates a multimodal approach to learning, catering to diverse learning preferences. The platform not only provides flexibility in accessing educational resources but also promotes active student engagement, independent learning skills, and problem-solving abilities. Through its implementation, this study aims to demonstrate the effectiveness of the platform in enhancing the learning experience for biology students, fostering a deeper understanding and application of knowledge. The findings of this study have broad implications for educators, policymakers, and researchers in the field of education technology. Educators can benefit from the insights gained regarding the factors influencing e-learning adoption, enabling them to design and implement more effective online learning experiences. Policymakers can use the findings of this study to inform the development of policies and initiatives that promote e-learning adoption and ensure equitable access to technology and resources. Researchers in the field of education technology can build upon the findings of this study to further explore the factors affecting e-learning adoption and investigate innovative approaches to enhance distance learning program design. This study contributes to the growing body of knowledge in this field, paving the way for evidence-based practices and advancements in educational technology, ultimately improving the quality and accessibility of education.

2- Theoretical Background

Behavioral intention to adopt and engage in e-learning activities refers to an individual's readiness and willingness to use and participate in e-learning platforms or educational resources. It represents the individual's intention to engage in e-learning activities, such as attending online courses, accessing digital learning materials, or using online tools for educational purposes. The literature provides various definitions and explanations of behavioral intentions to adopt e-learning. One widely used theoretical framework for understanding behavioral intention is the Technology Acceptance Model (TAM), which has been applied to e-learning contexts. According to the TAM, behavioral intention is influenced by two main factors: perceived usefulness and perceived ease of use [23]. In this study, the effect of three other factors, namely attitudes toward e-learning, flexibility, and quality of content, on students' behavioral intentions to adopt and engage in e-learning activities is investigated. In the following, each of these factors is discussed, and then the hypotheses of this study are developed to design the theoretical framework of this study.

2-1- E-Learning

E-learning refers to the use of electronic technologies and media to deliver educational content, facilitate interactions, and support learning outcomes across space, time, and various learning contexts [12]. E-learning encompasses online learning, blended learning, technology-enhanced learning, web-based training, and distance education enabled through digital tools and content delivery platforms. The origins of e-learning can be traced back to early forms of distance education that utilized mail correspondence, television, and radio to provide remote instruction. However, the rise of personal computing, the internet, multimedia, and communication technologies has accelerated the development of e-learning. The term became popular in the late 1990s as online learning platforms proliferated, although some ambiguities around the definition persist [24].

Various developments have expanded the scope, capabilities, and reach of e-learning. Growth in learning management systems, massively open online courses (MOOCs), social media, mobile devices, simulations, artificial intelligence, and immersive technologies has enhanced how content is delivered, social connections formed, skills developed, and learning personalized [25]. E-learning has diffused across educational sectors, workplace training, and informal learning contexts. Approaches such as blended learning integrate online and in-person instructions. Pedagogical advancements emphasize learner-centered, interactive, and personalized experiences enabled by technology [26]. E-learning has been applied across many disciplines and learning contexts. In healthcare education, e-

learning helps develop clinical skills and knowledge through simulations, virtual patients, and distance training [27]. For engineering students, it facilitates remote access to tools, collaboration, and practical learning [28]. In teacher education, interactive platforms and digital content help technology integration skills development [29]. Across contexts, e-learning platforms allow learning analytics to track engagement patterns and customize support [30]. However, achieving meaningful e-learning outcomes depends on aligning technologies with learners' needs, knowledge domains, and instructional goals. Implementations often fail when they lack usable designs, preparation, and organizational support [31]. Students value flexible access but require interactivity, structure, applicability, and social connections to persist and succeed [32]. Instructors need training and experience designing effective online learning activities that match content areas and pedagogies [33]. Successful adoption of e-learning requires careful integration of technological capabilities with instructional purposes.

Looking ahead, several promising areas may shape the ongoing evolution of e-learning. Creating adaptive systems that respond to learners' knowledge, interests, and contexts could enhance personalization [34]. Leveraging immersive technologies such as augmented and virtual reality for experiential learning is another frontier [35]. Learner analytics and AI tutor capabilities provide further opportunities to individually tailor and optimize e-learning. However, thoughtfully embedding technologies within sound pedagogical strategies remains critical for meaningful educational outcomes.

2-2- Concerns-Based Adoption Model (CBAM)

The Concerns-Based Adoption Model (CBAM) is a framework and methodology developed in the early 1970s to describe, measure, and explain the process of teacher change as they implement new curriculum and instructional practices in their classrooms [36]. According to Anderson [36], the key components of CBAM include:

- Assumptions about teacher change as a developmental process affecting feelings, skills, and behaviors. Change is seen as highly personal, facilitated through interventions, and involving growth through stages.
- The Stages of Concern (SoC) framework describes teacher attitudes and motivations regarding innovation. This ranges from awareness to information seeking, personal concerns, management concerns, consequence concerns, collaboration concerns, and refocusing on modifications or alternatives.
- The Levels of Use (LoU) framework focused on teacher behaviors as they progressed from non-use to preparation, mechanical use, routine use, refinement, integration, and renewal. This represents an increasing mastery of innovation.
- Innovation Configurations (IC) refers to the different ways teachers implement innovation in practice. IC checklists identify key components and variations in implementation across users.
- Concepts related to change facilitators, interventions, and context influencing the change process.

Some studies explored relationships between CBAM measures and factors such as school climate [37], course design implementation [38], teachers implementing new technologies [39, 40], educational change implementation [41], and class management [42]. The literature shows that CBAM remains relevant for understanding teacher change but needs revived theoretical development through more critical analysis and research.

2-3- Technological Pedagogical Content Knowledge (TPACK)

Technological Pedagogical Content Knowledge (TPACK) is a framework for teachers' knowledge base to effectively integrate technology into teaching. TPACK identifies the interconnected components of content, pedagogy, and technology knowledge required for successful technology integration [33]. The concept of TPACK originated from Shulman's (1986) pedagogical content knowledge (PCK) framework, which recognized that teaching required an understanding of how to transform subject matter knowledge for instruction. Mishra and Koehler [33] added technology knowledge as an essential component, arguing that teachers needed to understand how technology interacts with pedagogy and content to be used effectively. Their emphasis was on the connections between knowledge domains rather than treating them independently [43].

Since its introduction, various perspectives on TPACK have emerged. Some view TPACK as an extended PCK, with technology augmenting existing domains. Others see TPACK as a distinct body of knowledge that teachers must develop. More integrative perspectives highlight the interplay between content, pedagogy, and technology, situated within specific teaching contexts [43, 44]. There have also been critiques of vagueness in defining the boundaries between TPACK components [45]. Despite conceptual ambiguities, TPACK has been widely used in research and practice related to teachers' technology integration knowledge and skills. For example, TPACK frameworks have been used to develop technology integration courses for preservice teachers [29], assess in-service teachers' capacities [46], design professional development programs [47], and evaluate technology-related teacher education outcomes [33]. Studies suggest that active engagement in technology-enhanced lesson design and curriculum development activities can foster TPACK growth in teachers [48]. However, more research is required to clarify TPACK development trajectories within specific subject areas and teaching contexts [43].

While TPACK provides an intuitive model of technology integration knowledge domains, challenges remain in effectively measuring teachers' TPACK. Self-report surveys have been the most common, but variations in instrumentation and issues confirming construct validity persist [45, 49]. Performance assessments and observations offer alternatives aligned with situated perspectives on teacher knowledge, but valid protocols remain underdeveloped [50]. This is an active area of methods research [49].

2-4- Technology Acceptance Model (TAM)

Technology acceptance models are theoretical frameworks that explain and predict user acceptance and adoption of new technologies. The key idea is that a user's behavioral intention to use a technology system is determined by their perceptions of its usefulness and ease of use [23]. The origins of technology acceptance models can be traced back to the Theory of Reasoned Action (TRA) by Fishbein & Ajzen [51], who posited that behavior is driven by behavioral intentions, a function of attitudes toward the behavior and subjective norms. Building on the TRA, the Technology Acceptance Model (TAM) was introduced by Davis in 1986 and published in 1989. TAM focuses specifically on users' acceptance of information systems, replacing many TRA attitude measures with just two technology acceptance measures - perceived usefulness and perceived ease of use. TAM theorizes that perceived usefulness and perceived ease of use determine an individual's intention to use a system, which in turn predicts actual usage behavior. TAM has become one of the most widely used models for understanding user acceptance and usage behavior of new technologies [52]. Since its introduction, TAM has undergone various developments and expansions. For example, TAM2 added theoretical constructs spanning social influence and cognitive processes to explain perceived usefulness and intentions [53]. The Unified Theory of Acceptance and Use of Technology (UTAUT) integrated TAM with other models such as the Theory of Planned Behavior, identifying additional determinants of intention and behavior [9]. TAM3 incorporated both perceived ease of use and perceived usefulness determinants in a unified model [54].

TAM has been extensively applied to predict the adoption of a wide range of technologies, including mobile services, e-commerce, enterprise systems, and healthcare technologies. For example, Chatterjee et al. [55] used TAM to examine the adoption of mobile payment services, finding ease of use, usefulness, and social influences as key determinants. Gefen et al. [56] found TAM useful for explaining online shopping behavior. TAM has also been useful in healthcare for understanding physicians' adoption of electronic medical records [57]. The adaptability of TAM likely explains its popularity among technology adoption researchers.

Although TAM continues to be widely used, some issues and limitations have been raised. Bagozzi [58] critiqued the limited focus of TAM on utilitarian drivers and called for an examination of emotional, social and cultural factors. Cao et al. [59] highlighted the need to incorporate additional theoretical perspectives such as habit and power. Some researchers have also called for more qualitative research on technology adoption using TAM [52]. As such, the model is still evolving through integration with complementary theories and perspectives.

3- Hypothesis Development

3-1- Perceived Usefulness

Perceived usefulness refers to the extent to which individuals believe that using a particular technology, such as e-learning, will enhance their performance and contribute to achieving their learning goals. The perceived usefulness of e-learning, including its relevance and effectiveness in achieving learning goals, can significantly impact students' intention to adopt it [23]. This is a subjective evaluation of the potential benefits and advantages associated with adopting and using e-learning platforms and tools. Davis [23] proposed the Technology Acceptance Model (TAM), which suggests that perceived usefulness is a critical factor influencing users' acceptance and intention to use technology. Moon & Kim [60] extended the TAM framework to the World Wide Web context, further emphasizing the importance of perceived usefulness in users' adoption of web-based technologies. Based on the literature, it can be hypothesized that perceived usefulness is a factor affecting students' behavioral intention to adopt e-learning. Specifically, the higher perceived usefulness of e-learning platforms and tools will be positively associated with an increased intention of students to adopt and engage in e-learning activities. Therefore, the first hypothesis (H1) of this study is formulated as follows:

H1: The perceived usefulness of e-learning platforms positively affects students' behavioral intention to adopt and engage in e-learning activities.

3-2- Perceived Ease of Use

Perceived ease of use refers to the degree to which individuals perceive that using a specific technology, such as e-learning, is effortless and free from complexity. This relates to the perceived simplicity of navigating through the e-learning system, understanding its functionalities, and interacting with the available tools and resources. Perceived ease of use refers to students' perception of how easy it is to use e-learning platforms and tools. If students find e-

learning systems user-friendly and accessible, they are more likely to adopt them [9]. In TAM, Davis [23] considers perceived ease of use as a key factor influencing users' acceptance and intention to use technology. Venkatesh & Davis [61] further developed the TAM by providing a detailed model of the antecedents of perceived ease of use. Park [62] applied the TAM in the context of e-learning and demonstrated its relevance in understanding students' intention to use e-learning systems. Based on the literature, it can be hypothesized that perceived ease of use is a factor affecting students' behavioral intention to adopt e-learning. Specifically, higher perceived ease of use of e-learning platforms and tools will be positively associated with an increased intention of students to adopt and engage in e-learning activities. Hence, the second hypothesis (H2) of this study is written as follows:

H2: Perceived ease of use of e-learning platforms positively affects students' behavioral intention to adopt and engage in e-learning activities.

3-3- Attitude Toward E-Learning

Attitude toward e-learning refers to the overall evaluative perception, beliefs, and feelings that individuals hold toward using e-learning platforms and engaging in online learning activities. Students' overall attitude, beliefs, and opinions on e-learning can influence their intention to adopt it. Positive attitudes toward online learning are more likely to lead to adoption [8].

Attitude to using technology is a central construct influencing users' acceptance and intention to use technology in Davis et al. [63] TAM theory as well. Venkatesh et al. [9] further developed the Unified Theory of Acceptance and Use of Technology (UTAUT), which includes attitude as a key determinant of technology acceptance. Teo [64] applied the UTAUT model in the context of teachers' intention to use technology and demonstrated the importance of attitude in influencing their adoption behavior. Based on the literature, it can be hypothesized that attitude toward e-learning is a factor affecting students' behavioral intention to adopt e-learning. Specifically, a positive attitude to e-learning will be positively associated with an increased intention of students to adopt and engage in e-learning activities. Thus, the third hypothesis (H3) of this study is considered as follows:

H3: Attitude toward e-learning positively affects students' behavioral intention to adopt and engage in e-learning activities.

3-4- Flexibility

Flexibility in the context of e-learning refers to the extent to which students perceive that online learning provides them with opportunities for personalized learning experiences, self-paced learning, and the ability to access course materials and resources at any time and from any location that suits their needs and preferences. Cho and Heron [65] explored the role of flexibility in self-regulated learning in an online context, highlighting its importance in motivating and engaging students in online learning activities. Al-Fraihat et al. [66] conducted an empirical study to evaluate the success of e-learning systems, and flexibility emerged as one of the critical factors contributing to user satisfaction and acceptance. Dimitrova et al. [67] conducted a study in the Global Campus project at Middlesex University to explore the differences in learning styles between distance and classroom students. They examined the electronic learning resources and pedagogical approaches to determine how effectively they accommodated the diverse learning styles of students. Their findings emphasized the importance of flexibility in e-learning environments to meet the diverse needs of learners. Besides, Alrawi & Jaber [68] discussed the flexibility of e-learning in Gulf universities. They highlighted the benefits of e-learning as an alternative learning method and its increasing adoption in the educational industry. Their research emphasized the role of flexibility in e-learning in maximizing technology and creating successful web instructors. Based on the literature, it can be hypothesized that flexibility is a factor affecting students' behavioral intention to adopt e-learning. Specifically, higher perceived flexibility in terms of personalized learning experiences, self-paced learning, and accessibility will be positively associated with an increased intention of students to adopt and engage in e-learning activities. Consequently, the fourth hypothesis (H4) of this study is articulated as follows:

H4: Flexibility provided by e-learning positively affects students' behavioral intention to adopt and engage in e-learning activities.

3-5- Content Quality

Content quality refers to the overall quality, relevance, and effectiveness of educational content provided in e-learning environments. High-quality content that is relevant, engaging, and well-designed can significantly impact students' perception of the value and effectiveness of e-learning. High-quality content plays a crucial role in engaging students, promoting effective learning experiences, and influencing their intention to adopt e-learning. Ehlers [69] emphasizes the importance of learner orientation and the need to determine learners' needs before starting an e-learning project. It highlights that the quality of the learning process in e-learning is a co-production between the learner and the learning environment, and it should empower and enable the learner. In addition, Pham et al. [70]

investigated the relationships between e-learning service quality attributes, overall e-learning service quality, e-learning student satisfaction, and e-learning student loyalty. The findings indicate that e-learning service quality, including factors such as e-learning system quality, e-learning instructor and course materials quality, and e-learning administrative and support service quality, significantly influences overall student satisfaction and loyalty. Therefore, the fifth hypothesis of this study is considered as follows:

H5: The quality of the content of e-learning material positively affects students' behavioral intention to adopt and engage in e-learning activities.

The theoretical framework depicted in Figure 1 outlines the key factors influencing students' behavioral intention to adopt and engage in e-learning activities. This study proposes several hypotheses based on these factors. Firstly, the perceived usefulness of e-learning platforms is hypothesized to have a positive effect on students' behavioral intention. Secondly, the perceived ease of use of e-learning platforms is expected to positively influence students' behavioral intentions. Thirdly, attitude toward e-learning is hypothesized to have a positive impact on students' behavioral intentions. Additionally, the flexibility provided by e-learning and the quality of the content of e-learning material are hypothesized to positively affect students' behavioral intention. These hypotheses form the foundation of the current study, which aims to examine the relationships between these variables and provides insights into the effectiveness of e-learning in improving student outcomes.

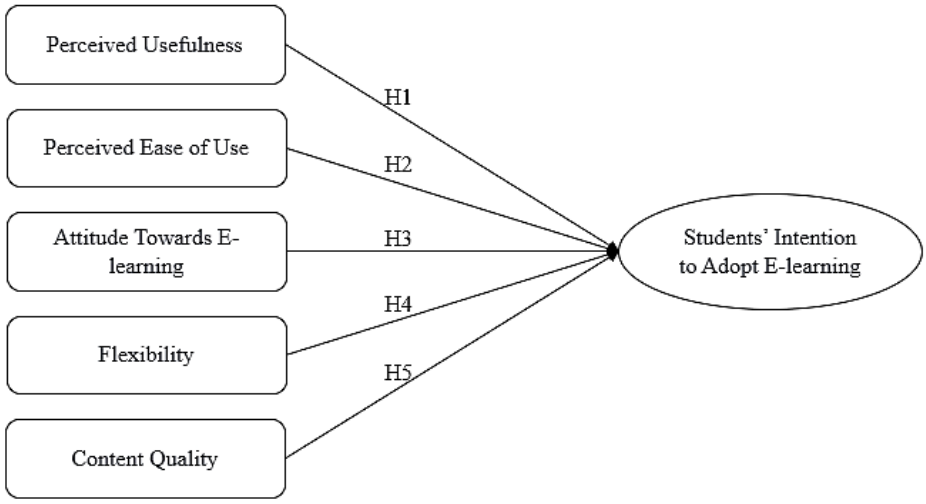

Figure 1. Theoretical framework and the first five hypotheses of the study

3-6- Online Learning and Student Performance

By leveraging the power of online platforms, online courses engage students in interactive learning experiences, fostering a deeper understanding of the subject concepts. The program incorporates multimedia resources, virtual laboratory simulations, online discussions, and collaborative projects to enhance student engagement and promote active learning. Through the implementation of this distance learning program, the study seeks to explore the potential benefits of online platforms in enhancing students' performance and learning outcomes in the field of biology. A systematic review by McCutcheon et al. [71] examined the effectiveness of online and blended learning in teaching clinical skills in undergraduate nursing education. The review identified 19 published papers, with the majority focusing on online approaches. The synthesis of findings highlighted that online learning for teaching clinical skills is no less effective than traditional methods. This review provides evidence to support the idea that online learning can be effective in enhancing learning outcomes. Gopal et al. [72] investigated the impact of online classes on student satisfaction and performance during the COVID-19 pandemic. This study collected data from 544 students studying business management or hotel management courses in Indian universities. The results showed that factors such as the quality of the instructor, course design, prompt feedback, and student expectations positively influenced student satisfaction, which, in turn, positively impacted their performance. This study provides evidence that online courses can result in high levels of satisfaction and performance. These studies show that online learning can be effective in enhancing learning outcomes and student satisfaction. Therefore, it is reasonable to expect that students who participate in a course delivered through an online platform will demonstrate higher performance in the final test compared with those who receive traditional offline learning. Therefore, the sixth hypothesis of this study is as follows:

H6: Online learning increases students' performance in the final test compared with traditional offline learning.

4- Research Methodology

4-1- Phase 1

The first phase of the study aimed to identify the factors that affect students' intention to adopt e-learning. The participants in this phase were 92 students from general secondary school No. 5 named after G. Muratbayev in Turkestan, Turkestan region, Kazakhstan. The study included 92 students who participated in both phases of the research. The population of the school consisted of 1140 students, and among them, 92 students expressed their interest in the field of biology. Therefore, the entire sample of 92 students was included in the study to ensure representation from the population of interest. Table 1 summarizes the demographic characteristics of the study participants. It shows that 46% of the participants are male and 54% are female, indicating a relatively balanced gender distribution among the 92 students. The age range of the participants is 15–18 years, with the majority in the 10th and 11th grades. This approach allowed for a comprehensive examination of the factors and outcomes related to the development of an online course (for the second phase of the study). By including the entire interested population, this study captured a diverse range of perspectives and experiences among the students. The study was conducted from 2020 to 2022. A questionnaire was designed by the authors on the basis of a 5-point Likert scale to collect data from the participants. The questionnaire consisted of items related to the factors influencing students' intention to adopt e-learning. The response options ranged from 1 (strongly disagree) to 5 (strongly agree). The questionnaire items are presented in Table 2.

Table 1. Demographic features of the participants in this study

Parameter	Study Information
Gender	Male: 46%, Female: 54%
Age Range	15-18 years old
Grade Level	10th and 11th
Country	Kazakhstan
Region	Turkestan Region
Location	Turkestan
School Name	General Secondary School No. 5
Participants	92 students

Table 2. Questionnaire items

Question Code	Factors	Questions
	Perceived usefulness:	
Q1		Overall, I find e-learning platforms to be useful for my learning.
Q2		E-learning platforms enhance my understanding of the course material.
Q3		E-learning platforms provide me with valuable resources and materials.
Q4		E-learning platforms improve my learning experience compared to traditional methods.
Q5		I believe that using e-learning platforms will help me achieve my academic goals.
	Perceived ease of use:	
Q6		I find it easy to navigate and use e-learning platforms.
Q7		Learning through e-learning platforms is intuitive and user-friendly.
Q8		I am comfortable using the features and tools available on e-learning platforms.
Q9		E-learning platforms make it convenient for me to access and interact with course materials.
Q10		I believe that using e-learning platforms requires minimal effort and technical skills.
	Attitude toward e-learning:	
Q11		I have a positive attitude toward learning through e-learning platforms.
Q12		I believe that e-learning platforms offer valuable learning opportunities.
Q13		I enjoy engaging in online activities and discussions on e-learning platforms.
Q14		E-learning platforms have positively influenced my perception of online learning.
Q15		I am motivated to actively participate in e-learning activities due to my positive attitude.

	Flexibility:
Q16	The flexibility offered by e-learning platforms allows me to study at my own pace.
Q17	E-learning platforms enable me to access course materials and resources anytime, anywhere.
Q18	The flexibility of e-learning platforms allows me to effectively balance my academic and personal commitments.
Q19	I appreciate the convenience of choosing when and where to engage in e-learning activities.
Q20	The flexibility provided by e-learning platforms enhances my overall learning experience.
	Content Quality:
Q21	The content presented on the e-learning platforms is relevant and aligned with the course objectives.
Q22	The e-learning materials provided are well organized and easy to understand.
Q23	The quality of the multimedia elements (e.g., videos, interactive modules) enhances my learning experience.
Q24	The e-learning content is engaging and holds my attention throughout the course.
Q25	The quality of the content on e-learning platforms contributes to my overall satisfaction with the learning experience.

The collected data were analyzed using structural equation modeling (SEM) with SmartPLS 4.0 software. SEM allowed for the examination of the relationships between the factors and students' intention to adopt e-learning.

Table 3 summarizes the results of the validity and reliability analysis for each factor. The reported measures include Cronbach's alpha, composite reliability (CR), and average variance extracted (AVE). These results indicate the validity and reliability of the data collection tool for each factor. For the factor "Perceived Usefulness," the Cronbach's alpha is 0.731, the composite reliability is 0.775, and the average variance extracted is 0.693. For the factor "Perceived Ease of Use," the Cronbach's Alpha is 0.768, the composite reliability is 0.738, and the average variance extracted is 0.515. For the factor "Attitude Towards E-learning," the Cronbach's alpha is 0.859, the composite reliability is 0.799, and the average variance extracted is 0.658. For the factor "Flexibility," the Cronbach's alpha is 0.788, the composite reliability is 0.746, and the average variance extracted is 0.579. For the factor "Content Quality," the Cronbach's alpha is 0.703, the composite reliability is 0.750, and the average variance extracted is 0.616. These results suggest acceptable to good levels of validity and reliability for the respective factors. Cronbach's alpha values range from 0.703 to 0.859, indicating satisfactory internal consistency. The composite reliability values range from 0.738 to 0.799, suggesting reliable measurements. The average variance extracted values range from 0.515 to 0.693, indicating convergent validity.

Table 3. Validity and reliability results for the factors in the study

Factors	Cronbach's Alpha	CR	AVE
Perceived Usefulness	0.731	0.775	0.693
Perceived Ease of Use	0.768	0.738	0.515
Attitude toward E-learning	0.859	0.799	0.658
Flexibility	0.788	0.746	0.579
Content Quality	0.703	0.750	0.616

Testing loading factors is an essential step in the process of validating a measurement instrument or questionnaire. Loading factors represent the strength of the relationship between the observed indicators (items) and the underlying constructs they are intended to measure. By testing loading factors, researchers can evaluate the extent to which the items accurately capture the intended constructs. Strong loading factors indicate that the items are highly representative of the underlying constructs, thereby providing evidence of construct validity. Additionally, testing loading factors helps to identify any weak or insignificant relationships, which may suggest the need for item revision or removal. Furthermore, assessing loading factors allows researchers to ensure that the items are reliable and consistent in measuring the constructs of interest. Therefore, testing loading factors is crucial for establishing the validity and reliability of a measurement instrument, enabling researchers to make confident interpretations and draw meaningful conclusions from their data.

Table 4 presents the results of loading factor analysis using SmartPLS. The loading factors for all 25 items of the questionnaire are above the threshold of 0.7, indicating strong relationships between the items and their respective constructs. Additionally, all loading factors are statistically significant as their p-values are below the significance level of 0.05. The mean, standard deviation, and p-values for each question are also provided in the table.

Table 4. Loading factor analysis

Question Code	Loading Factors	Mean	Standard Deviation	P-value
Q1	0.803	4.38	0.970	0.022
Q2	0.835	4.09	1.350	0.011
Q3	0.938	4.02	1.420	0.041
Q4	0.740	4.28	1.410	0.021
Q5	0.776	4.11	1.400	0.012
Q6	0.821	4.13	1.070	0.035
Q7	0.866	3.31	1.310	0.050
Q8	0.830	4.62	1.330	0.045
Q9	0.916	4.18	1.190	0.013
Q10	0.736	4.40	1.360	0.033
Q11	0.913	4.64	1.170	0.044
Q12	0.739	3.75	0.980	0.034
Q13	0.804	4.18	1.170	0.050
Q14	0.880	3.63	0.980	0.047
Q15	0.774	4.04	0.890	0.029
Q16	0.903	3.93	1.290	0.043
Q17	0.749	4.03	1.310	0.045
Q18	0.819	3.99	1.100	0.021
Q19	0.955	3.70	1.120	0.043
Q20	0.941	4.63	1.250	0.036
Q21	0.809	3.70	1.430	0.049
Q22	0.930	4.02	1.340	0.015
Q23	0.778	3.10	1.250	0.027
Q24	0.786	3.38	1.170	0.036
Q25	0.956	3.87	1.340	0.015

4-2- Phase 2

The second phase of the study aimed to develop and implement a distance learning program for teaching biology to students, specifically a course entitled "Humans and Their Health." Based on the results of Phase 1, a network-based educational and methodological framework was developed. The two phases of this study are interconnected and built upon each other to achieve a comprehensive understanding of the students' adoption of e-learning and its application in the field of biology education. The first phase focuses on identifying the factors that influence students' intention to adopt e-learning. By investigating these factors, such as perceived usefulness, ease of use, and flexibility, this study aims to gain insights into students' attitudes and behaviors toward online learning platforms. This understanding is crucial because it provides a foundation for the second phase, which involves the development and implementation of a distance learning program for teaching biology, titled "Humans and Their Health." By examining the factors that affect students' intention to adopt e-learning in the first phase, the study can inform the design and delivery of the distance learning program, ensuring that it addresses the identified factors and aligns with students' needs and preferences. Thus, the first phase of this study serves as a critical precursor to the second phase, laying the groundwork for an effective and tailored distance learning program that enhances students' engagement and learning outcomes in the field of biology. The distance learning program developed for teaching biology to students in this study is titled "Humans and Their Health." This online course is designed to provide students with a comprehensive understanding of the intricate relationship between human beings and their health.

The experiment consisted of three stages: defining experiment, formative experiment, and control experiment. These stages were designed to gradually introduce and implement distance learning methodologies and evaluate their effectiveness. The biology course focused on various aspects of biological knowledge, including morphological, anatomical, physiological, ecological, hygienic, and medical concepts. The course aimed to develop students' understanding of the human body and its functions while fostering independent learning skills.

To deliver the course, an online educational and methodological framework was created. The framework included interactive resources such as an interactive whiteboard, video communication tools, instant comment exchange, and access to various educational materials. Students could access the framework using their home computers or the computers provided to them by the state as part of the distance learning program. The course material was presented in

a multimedia format, incorporating oral explanations from teachers, interactive illustrations, tasks, animated illustrations, videos, and presentations. The course emphasized independent learning and self-education skills, encouraging students to actively engage in the learning process. As students progressed through the course, the proportion of independent work increased, including practical tasks, control tasks, and studying new material. The course also incorporated interdisciplinary connections to enhance students' understanding of biological concepts. It encouraged the exploration of knowledge from various disciplines and real-life experiences, fostering critical thinking and problem-solving skills.

The student experience in the distance learning course involved participating in the scheduled individual classes within the online educational and methodological framework. Students and teachers interacted in a shared virtual space, using video communication and instant comments for discussions and demonstrations.

The course structure allowed students to work through the material at their own pace, reviewing and consolidating their understanding through independent study. The use of interactive tasks, video conferences, and self-measurements (e.g., heart rate, pulse, blood pressure) further engaged students and promoted active learning. To support students' familiarity with the online educational and methodological framework, introductory classes were conducted at the beginning of the course. Computer science teachers and computer technicians provided guidance on technical aspects, such as searching for educational material, registration, and login procedures. Throughout the course, the teacher played a crucial role in guiding students, providing clear instructions, and establishing cause-and-effect relationships between concepts. The teacher facilitated discussions, analysis, and synthesis of the material to enhance students' comprehension and self-study abilities.

The experimental group received instruction through this framework, whereas the control group did not receive any special interventions. A total of 92 students from general secondary school No. 5 named after G. Muratbayev in Turkestan, Turkestan region, Kazakhstan participated in this phase. The experimental group consisted of 46 students, and the control group also consisted of 46 students. The study was conducted from 2020 to 2022.

In contrast to the experimental group, the control group in this study received traditional in-person instruction. In the control group, the biology course material was delivered through conventional classroom teaching methods, where the lecturer presented the course content in a face-to-face setting. Unlike the experimental group, which used modern information and communication technologies for distance learning, the control group's instruction followed the traditional classroom model. The control group's experience involved direct interactions with the teacher in a physical classroom environment, without the use of the online educational and methodological framework employed in the experimental group. The purpose of this control group was to provide a baseline for comparison in evaluating the effectiveness of the distance learning approach introduced in the experimental group. It is noteworthy that the same participants were utilized for both phases of the study, ensuring consistency in the sample across phases. During the first phase, questionnaire administration occurred during regular school hours, with direct oversight by one of the researchers from the study team, although the overall process was managed collaboratively with the school manager and a teacher. Furthermore, the identical course content, referred to as "Humans and Their Health" in the field of biology, was delivered to both the control and experimental groups, but it was not administered to the entire school population. This approach allowed for a controlled evaluation of the impact of the distance learning methodology introduced in the experimental group compared with the traditional classroom teaching method used in the control group.

Data analysis for this phase involved conducting an independent sample t-test to compare the performance of the students in the experimental group with that of the control group. The focus was on evaluating the difference in students' performance. Factors such as students' access to technology and the suitability of the distance learning environment were also considered. Overall, the study employed a mixed-methods approach, including data collection through questionnaires and statistical analysis techniques, to examine the factors influencing students' intention to adopt e-learning and assess the impact of the developed distance learning program on students' performance in the "Humans and Their Health" course.

It is essential to note that the evaluation of students' performance in this course carried official weight, with grades being considered as part of their academic records. While participation in the study was voluntary, as evidenced by the inclusion of students from grades 10 and 11, the course itself was designated as an elective course, meaning it was not obligatory but rather one of several elective courses available to students during their study period. This elective course requirement mandated that students complete at least one elective course, with "Humans and Their health" being one of the options. Consequently, the study encompassed a representative age group within the school, comprising both 10th and 11th grade students, and their performance in the course was officially recognized within the academic framework.

5- Results

5-1- Hypothesis Testing

H1: The perceived usefulness of e-learning platforms positively affects students' behavioral intention to adopt and engage in e-learning activities.

Hypothesis H1 stated that perceived usefulness of e-learning platforms positively affects students' behavioral intention to adopt and engage in e-learning activities. The results of hypothesis testing, as summarized in Table 5, revealed a significant positive relationship between perceived usefulness and e-learning adoption (β = 0.331, p = 0.041). This confirms the hypothesis and indicates that when students perceive e-learning platforms as useful, they are more likely to show behavioral intention to adopt and engage in e-learning activities. The findings suggest that the perceived utility of e-learning platforms plays a crucial role in shaping students' attitudes and willingness to embrace online learning. This underscores the importance of designing and providing e-learning platforms that are perceived as useful for enhancing student engagement and participation in online educational activities.

Table 5. Relationship between perceived usefulness and e-learning adoption

	Hypotheses	β	S.D.	p Values	Result
H1	Perceived Usefulness → E-learning Adoption	0.331	1.317	0.041	Confirmed

H2: Perceived ease of use of e-learning platforms positively affects students' behavioral intention to adopt and engage in e-learning activities.

Hypothesis H2 proposed that perceived ease of use of e-learning platforms positively affects students' behavioral intention to adopt and engage in e-learning activities. The results of hypothesis testing, as summarized in Table 6, indicate a significant positive relationship between perceived ease of use and e-learning adoption (β = 0.462, p = 0.023). This confirms the hypothesis and suggests that when students perceive e-learning platforms as easy to use, they are more likely to demonstrate behavioral intention to adopt and engage in e-learning activities. The findings highlight the importance of user-friendly and intuitive e-learning interfaces that facilitate students' navigation, interaction, and overall usability. Enhancing the ease of use of e-learning platforms can contribute to higher levels of student engagement and participation in online learning environments.

Table 6. Relationship between perceived ease of use and e-learning adoption

	Hypotheses	β	S.D.	p Values	Result
H2	Perceived Ease of Use → E-learning Adoption	0.462	0.968	0.023	Confirmed

H3: Attitude toward e-learning positively affects students' behavioral intention to adopt and engage in e-learning activities.

Hypothesis H3 proposed that attitude toward e-learning positively affects students' behavioral intention to adopt and engage in e-learning activities. The results of hypothesis testing, as summarized in Table 7, reveal a significant positive relationship between attitude to e-learning and its adoption (β = 0.512, p = 0.018). This confirms the hypothesis and indicates that students' positive attitudes toward e-learning are associated with a higher behavioral intention to adopt and engage in e-learning activities. This suggests that when students have a favorable perception of e-learning and hold positive beliefs about its effectiveness and value, they are more likely to embrace and actively participate in online learning. The findings emphasize the importance of nurturing a positive attitude to e-learning among students, as it can contribute to their overall acceptance and engagement in digital learning environments.

Table 7. Relationship between attitude toward e-learning and e-learning adoption

	Hypotheses	β	S.D.	p Values	Result
H3	Attitude toward E-Learning → E-learning Adoption	0.512	1.293	0.018	Confirmed

H4: Flexibility provided by e-learning, positively affects students' behavioral intention to adopt and engage in e-learning activities.

Hypothesis H4 proposed that flexibility provided by e-learning, positively affects students' behavioral intention to adopt and engage in e-learning activities. The results of hypothesis testing, as summarized in Table 8, demonstrate a significant positive relationship between flexibility and e-learning adoption (β = 0.414, p = 0.000). This provides strong evidence to confirm the hypothesis, indicating that when students perceive e-learning platforms to offer flexibility in terms of time, location, and pace of learning, they are more inclined to adopt and engage in e-learning activities. The findings highlight the importance of incorporating flexible features into online learning environments to accommodate the diverse needs and preferences of students. By allowing students to control their learning schedules and providing opportunities for self-paced learning, e-learning can enhance their behavioral intention to actively participate in online educational experiences.

Table 8. Relationship between flexibility and e-learning adoption

	Hypotheses	β	S.D.	p Values	Result
H4	Flexibility → E-learning Adoption	0.414	1.395	0.000	Confirmed

H5: The quality of the content of e-learning material positively affects students' behavioral intention to adopt and engage in e-learning activities.

Hypothesis H5 stated that the quality of the content of e-learning material positively affects students' behavioral intention to adopt and engage in e-learning activities. The results of hypothesis testing, as presented in Table 9, reveal a significant positive relationship between content quality and e-learning adoption ($\beta = 0.712$, $p = 0.001$). These findings confirm the hypothesis, indicating that when students perceive the e-learning material to be of high quality, they are more likely to adopt and engage in e-learning activities. The results highlight the importance of providing well-designed and informative content in online learning platforms. Quality content not only enhances students' interest and motivation to participate in e-learning but also contributes to their learning outcomes and overall satisfaction with the online learning experience. By focusing on delivering high-quality educational materials, institutions can effectively promote students' intention to actively engage in e-learning and foster a positive learning environment.

Table 9. Relationship between content quality and e-learning adoption

	Hypotheses	β	S.D.	p Values	Result
H5	Content Quality → E-learning Adoption	0.712	1.012	0.001	Confirmed

The findings of this study provide strong support for the first five hypotheses, which examined the factors influencing e-learning adoption. The results, summarized in Tables 5 to 9, indicate that perceived usefulness, perceived ease of use, attitude toward e-learning, flexibility, and content quality all have a significant positive effect on students' behavioral intention to adopt and engage in e-learning activities. The relationship between these factors and e-learning adoption was found to be substantial, as indicated by the high R-square value of 0.74. This indicates that approximately 74% of the variance in students' behavioral intention to adopt e-learning can be explained by the combined influence of perceived usefulness, perceived ease of use, attitude toward e-learning, flexibility, and content quality.

These findings highlight the importance of considering these factors when designing and implementing e-learning initiatives. Ensuring that e-learning platforms are perceived as useful, easy to use, and flexible with high-quality content can significantly enhance students' intention to adopt and engage in e-learning. Furthermore, cultivating a positive attitude to e-learning among students can further contribute to their willingness to embrace online learning as an effective educational method. The substantial R-square value suggests that these factors collectively play a significant role in shaping students' decisions to adopt e-learning. Educators and institutions should focus on optimizing these factors to create a supportive and engaging e-learning environment that promotes active participation and positive learning outcomes.

H6: Online learning increases students' performance in the final test compared with traditional offline learning.

The sixth hypothesis of this study examined whether online learning would result in higher performance in the final test compared with traditional offline learning. The results of the hypothesis testing are summarized in Table 10.

Table 10. Comparison of performance in the final test between the experimental group (online learning) and control group (traditional offline learning)

	Experiment Group (n = 46)	Control Group (n = 46)	Test Stat
Mean Score	85.2	79.6	
Standard Deviation	6.7	7.3	
Levene's test:			
Test Statistic			1.52
Degrees of Freedom			1, 90
p-value			0.221
Independent t-test:			
t-value			2.18
Degrees of Freedom			90
p-value			0.034

The experimental group, consisting of 46 students who received instruction through the online learning platform, obtained a mean score of 85.2 on the final test. In contrast, the control group, comprising 46 students who received traditional offline learning, achieved a mean score of 79.6 on the same test. To determine the statistical significance of the difference in mean scores between the two groups, an independent t-test was performed. The t-value of 2.18 with 90 degrees of freedom resulted in a p-value of 0.034, which is below the significance level of 0.05. This indicates a statistically significant difference in the performance of the experimental group compared with that of the control group. Additionally, Levene's test was performed to assess the equality of variances between the two groups. The test statistic of 1.52 with 1 degree of freedom and 90 total degrees of freedom resulted in a p-value of 0.221, which is above the significance level of 0.05. This suggests that there is no significant difference in variance between the experimental and control groups. Overall, the results of the hypothesis testing provide evidence to support H6. The experimental group, which participated in online learning, demonstrated significantly higher performance in the final test than the control group, which received traditional offline learning. This suggests that online learning can be an effective method for enhancing students' academic achievement and underscores the potential benefits of incorporating online learning platforms into educational practices.

6- Findings and Discussion

The first hypothesis of this study stated that the perceived usefulness of e-learning platforms positively affects students' behavioral intentions to adopt and engage in e-learning activities. The finding that perceived usefulness has a positive impact on behavioral intention to adopt and engage in e-learning activities aligns with previous research in the field. Several studies have highlighted the significance of perceived usefulness as a determinant of individuals' intention to use and adopt technology-based platforms. For instance, Davis [23] on technology acceptance found that perceived usefulness was a crucial factor influencing users' intentions to adopt new technologies. This is consistent with the present study results, which show that students who perceive e-learning platforms as useful are more likely to have a positive behavioral intention toward using and engaging in e-learning activities.

The positive relationship between perceived usefulness and behavioral intention can be attributed to the benefits that students perceive when using e-learning platforms. When students perceive e-learning platforms as useful, they believe that these platforms will enhance their learning experience, provide access to a wide range of resources, and facilitate effective knowledge acquisition. This perception can motivate students to actively engage in e-learning activities and adopt the platform as a preferred mode of learning. The literature also supports the notion that perceived usefulness influences technology adoption. In the context of e-learning, studies have emphasized the role of perceived usefulness in determining students' intentions to adopt and use e-learning platforms. For instance, a study by Venkatesh and Davis (2000) on technology acceptance in education found that perceived usefulness significantly influenced students' intentions to adopt online learning systems.

Comparing these findings with the existing literature, our study provides further support for the importance of perceived usefulness in predicting students' behavioral intentions to adopt and engage in e-learning activities. The results highlight the need for e-learning platforms to prioritize and enhance perceived usefulness through features and functionalities that align with students' learning needs and preferences. It is important to note that while the results confirm the positive relationship between perceived usefulness and behavioral intention, further research is needed to explore the underlying mechanisms and factors that contribute to this relationship. Additionally, future studies could investigate the long-term effects of perceived usefulness on actual e-learning adoption and engagement to assess the sustainability of behavioral intentions.

The second hypothesis of this study stated that the perceived ease of use of e-learning platforms positively affects students' behavioral intentions to adopt and engage in e-learning activities. The finding that perceived ease of use has a positive impact on behavioral intention to adopt and engage in e-learning activities is consistent with previous research in the field. Numerous studies have highlighted the importance of perceived ease of use as a significant factor in technology acceptance and adoption. For instance, the Technology Acceptance Model (TAM) proposed by Davis [23] emphasizes the role of perceived ease of use in shaping individuals' intentions to use technology. According to the model, when users perceive a technology as easy to use, they are more likely to develop a positive attitude and intention to adopt it. In the context of e-learning, studies have consistently shown the influence of perceived ease of use on students' intentions to use e-learning platforms. For example, a study by Al-Fraihat et al. [66] on factors influencing students' intention to use e-learning platforms during the COVID-19 pandemic found that perceived ease of use significantly affected students' behavioral intention to engage in online learning. Similarly, a study by Parasuraman & Colby [73] on factors influencing students' intention to adopt e-learning technologies in higher education found that perceived ease of use was a significant predictor of intention. The positive relationship between perceived ease of use and behavioral intention can be explained by the notion that when students perceive e-learning platforms as easy to use, they are more likely to perceive them as accessible and user-friendly. This perception reduces perceived barriers and complexity associated with technology use, leading to a higher intention to adopt and engage in e-learning activities. Comparing these findings with the existing literature, our study adds further evidence to support the role of perceived ease of use in influencing students' behavioral intentions to adopt and engage in e-learning

activities. The results highlight the need for e-learning platforms to prioritize user-friendliness, simplicity, and intuitive design to enhance perceived ease of use and encourage students' intention to use the platforms. However, it is important to acknowledge that there may be individual differences in students' perceptions of ease of use, and factors such as digital literacy and prior experience with technology can influence this perception. Future research could explore these individual differences and investigate strategies to address potential barriers related to ease of use, ensuring that e-learning platforms cater to the diverse needs and technological competencies of students.

The third hypothesis of this study posited that attitude toward e-learning positively affects students' behavioral intention to adopt and engage in e-learning activities. The finding that attitude to e-learning has a positive impact on behavioral intention aligns with previous research in the fields of technology adoption and e-learning. Attitude refers to an individual overall evaluation or positive/negative affective response toward a particular technology or system. In the context of e-learning, a positive attitude to online learning has been consistently linked to a higher intention to engage in e-learning activities. Several theoretical models and studies have emphasized the role of attitude in influencing individuals' intentions to adopt and use technology. For instance, the TAM proposed by Davis [23] suggests that an individual attitude toward using a technology significantly affects their behavioral intention to use it. This model has been widely applied in e-learning research, and studies have consistently found that a positive attitude to e-learning predicts a higher intention to adopt and engage in online learning. In the broader context of educational technology, research has shown that positive attitudes to technology and e-learning are associated with various factors such as perceived usefulness, ease of use, enjoyment, value, and social influence. For example, a study by Huang & Liaw [74] on factors influencing students' intention to use e-learning platforms found that attitude was a significant predictor of intention, along with perceived usefulness and ease of use. Similarly, Kuo et al. [75] on factors influencing students' adoption of online learning platforms identified attitude as a key determinant of intention. The positive relationship between attitude toward e-learning and behavioral intention can be attributed to several factors. A positive attitude reflects a favorable perception of e-learning, including beliefs about its effectiveness, relevance to personal goals, and enjoyment of the learning experience. A positive attitude can also lead to greater motivation and engagement in e-learning activities, as individuals are more likely to approach online learning with enthusiasm and a proactive learning mindset.

Comparing the findings of this study with the existing literature, our results provide further support for the role of attitude in influencing students' behavioral intentions to adopt and engage in e-learning activities. The results underscore the importance of fostering positive attitudes toward e-learning among students, as it can positively impact their intention to use and actively participate in online learning platforms. Educators and instructional designers can contribute to shaping positive attitudes by emphasizing the benefits and advantages of e-learning, providing engaging and interactive learning experiences, and addressing students' potential concerns or misconceptions. It is also essential to consider individual differences in attitudes and factors that may influence them, such as prior experiences with e-learning, self-efficacy beliefs, and perceived social norms.

The fourth hypothesis of this study posited that flexibility provided by e-learning positively affects students' behavioral intentions to adopt and engage in e-learning activities. The finding that flexibility positively influences behavioral intention to adopt e-learning is consistent with previous research in the field of e-learning and technology adoption. Flexibility refers to the ability of e-learning platforms to provide learners with options for self-paced learning, access to course materials at any time and location, and the ability to personalize their learning experiences. Several theoretical models and studies have highlighted the significance of flexibility in influencing students' intentions to adopt and engage in e-learning activities. For instance, the Unified Theory of Acceptance and Use of Technology (UTAUT) proposed by Venkatesh et al. [9] suggests that perceived flexibility is one of the key determinants of individuals' behavioral intention to use technology. Studies applying UTAUT in the context of e-learning have consistently found that flexibility is an important factor influencing learners' intentions to adopt online learning platforms. The literature supports the notion that flexibility in e-learning can have several positive effects on learners' engagement and motivation. Flexible learning environments allow learners to tailor their learning experiences to their individual preferences, schedules, and learning styles. This flexibility enables students to take control of their learning process, promoting a sense of autonomy and empowerment. Additionally, flexible access to course materials and resources ensures that learners can review and revisit content as needed, fostering deeper understanding and mastery of the subject matter. Research has also shown that flexibility in e-learning can address various barriers to learning, such as geographical limitations, time constraints, and individual learning preferences. For example, a study by Rovai et al. [76] on the impact of online course structure on student satisfaction found that flexible course designs, allowing students to control the pace and timing of their learning, positively influenced their engagement and satisfaction with the course.

Comparing the findings of this study with the existing literature, our results provide further evidence of the positive relationship between flexibility and behavioral intention to adopt e-learning. The results highlight the importance of incorporating flexibility into e-learning platforms and instructional designs to enhance students' engagement and intention to participate in online learning activities. Educators and instructional designers can promote flexibility in e-learning by providing various options for accessing course materials, offering asynchronous learning opportunities,

and allowing learners to set their own learning pace. Designing modular course structures, incorporating interactive and self-paced learning modules, and providing opportunities for collaboration and discussion can also enhance flexibility and learner control within the e-learning environment.

The fifth hypothesis of this study posited that the quality of the content of e-learning material positively affects students' behavioral intentions to adopt and engage in e-learning activities. The finding that content quality positively influences behavioral intentions to adopt e-learning aligns with the existing literature on e-learning and technology adoption. The quality of e-learning content refers to the relevance, accuracy, comprehensibility, and pedagogical effectiveness of the educational materials provided in online courses. Numerous studies have emphasized the significance of content quality in influencing learners' engagement, satisfaction, and learning outcomes in e-learning environments. Quality content is essential for facilitating meaningful learning experiences, promoting knowledge retention, and supporting students' achievement of learning objectives. According to the Cognitive Theory of Multimedia Learning [77], instructional materials with high-quality content and appropriate multimedia elements can enhance learners' cognitive processing and information retention. Engaging and interactive multimedia elements, such as videos, graphics, animations, and simulations, can facilitate the understanding of complex concepts, promote active learning, and increase learners' motivation [78, 79]. Research has consistently shown that learners perceive high-quality content as more relevant, credible, and valuable, leading to higher levels of engagement and the intention to participate in e-learning activities. For example, Sun et al. [10] found that learners' perceived quality of content significantly influenced their satisfaction and continuance intention in e-learning environments.

This study contributes significantly to the field of biology education and e-learning, building upon insights from prior research. While the literature provides valuable perspectives on various aspects of biology education and e-learning, it predominantly focuses on specific areas such as curriculum alignment, online lecture styles, and the impact of online labs on student performance. However, the existing literature does not directly investigate the multifaceted factors influencing e-learning adoption among high school students in biology education. For instance, Camara [16] highlights the integration of Industrial Revolution 4.0 skills into senior high school biology curricula but does not explore the broader context of e-learning adoption. Choe et al. [17] underscore the importance of engaging lecture video styles but primarily emphasize content delivery methods rather than the factors influencing students' intent to adopt e-learning. Stuckey-Mickell & Stuckey-Danner [21] discuss student perceptions of virtual biology labs, but within the context of introductory courses, leaving a gap regarding factors influencing adoption among high school students.

In contrast, this study introduces a network-based educational methodological framework for biology education, addressing the dearth of literature that holistically examines the factors influencing e-learning adoption among high school students. By synthesizing concepts from the literature, particularly the significance of perceived usefulness, ease of use, attitude, flexibility, and content quality, this research offers a novel approach to modernizing and enhancing biology education through e-learning. This study builds upon prior studies by investigating these factors in the context of high school biology education, filling a notable research gap. Additionally, this study empirically demonstrates the potential of e-learning to improve students' academic performance, aligning with the broader trends in the literature that emphasize the effectiveness of multimedia and online resources in enhancing learning outcomes. Consequently, this research contributes to the academic discourse by offering practical insights and a comprehensive framework for educators, instructional designers, and policymakers seeking to optimize e-learning platforms in high school biology education, ultimately fostering more engaging and effective learning experiences.

To enhance content quality in e-learning, instructional designers and educators should consider the following practices:

- Needs assessment: Conduct thorough needs assessments to identify learners' preferences, prior knowledge, and learning goals, which can guide the development of relevant and targeted content.
- Clear organization: Structure the content in a logical and organized manner, making it easy for learners to navigate and access information.
- Visual aids: Incorporate visually appealing and informative graphics, images, and multimedia elements that support understanding and engagement.
- Interactivity: Integrate interactive elements such as quizzes, simulations, and problem-solving activities to promote active learning and learner engagement.
- Pedagogical strategies: Apply effective pedagogical strategies, such as scaffolding, formative assessments, and collaborative learning, to support learners' comprehension and application of the content.
- Continuous improvement: Regularly update and revise the e-learning content based on learner feedback, emerging trends, and advancements in the subject area.

The sixth hypothesis of this study investigated whether online learning increases students' performance in the final test compared with traditional offline learning. The findings of this study provide strong support for the hypothesis,

suggesting that online learning leads to improved performance in the final test compared with traditional offline learning. This aligns with previous research that has highlighted the benefits of online learning for enhancing student achievement and academic outcomes. A growing body of literature has demonstrated the positive impact of online learning on student performance. Online learning environments offer several advantages, such as flexibility in terms of time and location, access to various learning resources, and opportunities for personalized and self-paced learning experiences. These features contribute to increased student engagement, motivation, and active participation, which can translate into improved learning outcomes. Studies comparing online and traditional offline learning have consistently shown comparable or even superior student performance in online settings. For instance, a meta-analysis by Bernard et al. [80] found that online learning was associated with higher student achievement than face-to-face instruction. Similarly, Means et al. [81] reported that students in online learning conditions outperformed those in face-to-face classes. The advantages of online learning can be attributed to various factors. First, the interactive and multimedia-rich nature of online courses allows for engaging learning experiences. Students can access a variety of multimedia resources, such as videos, simulations, and interactive exercises, which can enhance their understanding and retention of the course content. Second, online learning often promotes self-regulated learning because students are responsible for managing their own learning pace, accessing resources, and engaging in self-assessment. This self-directed approach fosters autonomy, metacognitive skills, and deeper learning. Furthermore, online learning environments often provide opportunities for immediate feedback and adaptive learning experiences. Automated feedback, online assessments, and personalized learning pathways can assist students in monitoring their progress, identifying areas for improvement, and adjusting their learning strategies accordingly. However, it is important to acknowledge that the success of online learning in improving student performance is contingent upon various factors, including the design and implementation of the online course, the quality of instructional materials, the effectiveness of pedagogical strategies, and students' technological readiness and self-regulation skills.

6-1- Theoretical Contributions

The findings of this study make several theoretical contributions to the field of e-learning and educational research. First and foremost, this study provides empirical evidence for the relationships between various factors and students' behavioral intentions to adopt and engage in e-learning activities. By testing and confirming the hypotheses related to perceived usefulness, perceived ease of use, attitude toward e-learning, flexibility, and content quality, this study contributes to the existing theoretical knowledge in understanding the determinants of students' acceptance and engagement in e-learning platforms. Moreover, this study expands the literature by examining the impact of online learning on students' academic performance. The confirmation of the hypothesis that online learning increases students' performance in the final test compared to traditional offline learning highlights the potential benefits of online learning environments for fostering improved learning outcomes. This finding adds to the existing body of research that supports the advantages of online learning in enhancing student achievement and academic success. In addition, this study contributes to the understanding of the factors influencing e-learning adoption, specifically in the context of biology education. While previous research has investigated e-learning adoption in various domains, the application of these factors in the field of biology education provides domain-specific insights. This study highlights the importance of factors such as perceived usefulness, perceived ease of use, attitude to e-learning, flexibility, and content quality in shaping students' intentions to adopt and engage in e-learning activities in the context of biology education. Furthermore, the findings of this study have practical implications for educators, instructional designers, and policymakers. The identification and confirmation of the factors influencing students' behavioral intention to adopt e-learning activities provide valuable guidance for designing effective e-learning platforms and instructional materials. Educators can leverage the identified factors to enhance students' motivation, engagement, and learning outcomes in biology education.

7- Conclusions

In conclusion, this study aimed to investigate the factors influencing the adoption of e-learning platforms in biology education and examine the impact of online learning on student performance. The findings of this study provide valuable insights into the relationship between perceived usefulness, perceived ease of use, attitude toward e-learning, flexibility, content quality, and students' behavioral intention to adopt e-learning activities. Moreover, this study examined the effect of online learning on students' performance compared with traditional offline learning. Results of the study:

- Confirm the hypotheses related to the factors influencing e-learning adoption. Perceived usefulness, perceived ease of use, attitude toward e-learning, flexibility, and content quality had a significant positive impact on students' behavioral intention to adopt and engage in e-learning activities. These findings align with previous research in the field, which emphasizes the importance of these factors in shaping students' attitudes and behaviors to e-learning.
- Demonstrate that online learning significantly improves students' performance in the final test compared with traditional offline learning.

- Highlight the potential of e-learning platforms to enhance students' learning outcomes and academic achievement in biology education. The use of interactive multimedia resources, flexible learning options, and high-quality educational content in online courses contributed to increased engagement, independent learning skills, and the application of knowledge in problem-solving.

The theoretical contributions of this study lie in the identification and confirmation of the factors influencing e-learning adoption in the context of biology education. By examining the relationships between these factors and students' behavioral intention to adopt e-learning, this study contributes to the theoretical understanding of the factors that drive students' engagement in online learning activities.

Overall, this study underscores the potential of e-learning platforms in biology education and highlights the importance of factors such as perceived usefulness, ease of use, attitude, flexibility, and content quality in shaping students' adoption of e-learning. The findings contribute to the growing body of literature on e-learning adoption and provide practical insights for the design and implementation of effective online learning experiences in biology education. By leveraging the benefits of e-learning and incorporating innovative approaches, educational institutions can create engaging and inclusive learning environments that empower students and foster their academic success in biology education.

7-1- Recommendations

Based on the findings of this study, several practical recommendations can be made to enhance the implementation of e-learning platforms and improve biology education. These recommendations are aimed at educators, instructional designers, and policymakers:

- Promote the perceived usefulness and ease of use of e-learning platforms: Educators and instructional designers should emphasize the benefits and advantages of e-learning platforms in biology education. Highlighting the practical relevance and utility of online learning materials and resources can enhance students' perception of their usefulness. Additionally, efforts should be made to ensure that e-learning platforms are user-friendly and intuitive, thus providing a seamless learning experience for students.
- Foster a positive attitude toward e-learning: Educators should actively promote a positive attitude toward e-learning among students. This can be achieved by showcasing success stories, highlighting the advantages of online learning, and addressing any concerns or misconceptions. Creating a supportive and engaging learning environment that values and encourages e-learning can contribute to students' positive attitudes and increased adoption of online learning activities.
- Enhance flexibility in e-learning: E-learning platforms should provide flexible learning options that accommodate students' diverse needs and preferences. This can include allowing students to access learning materials at their own pace, providing opportunities for self-directed learning, and offering flexibility in assignment deadlines. By providing flexible learning experiences, e-learning platforms can cater to the individual learning styles and schedules of students, thereby promoting greater engagement and participation.
- Ensure high-quality content: It is crucial to prioritize the development and curation of high-quality educational content for e-learning platforms in biology education. Instructional designers and content creators should ensure that the materials are accurate, up-to-date, and aligned with the curriculum. Interactive and multimedia elements, such as videos, animations, and simulations, can be integrated to enhance the engagement and effectiveness of the learning experience. Regular review and updating of content are essential to maintain its relevance and quality.
- Provide training and support for educators: Educators play a vital role in the successful implementation of e-learning platforms. Therefore, providing adequate training and support to educators is crucial. Training programs can familiarize educators with the effective use of e-learning tools, strategies for online instruction, and methods to facilitate student engagement and interaction. Ongoing support and professional development opportunities can further enhance educators' confidence and competence in using e-learning platforms effectively.
- Consider the needs of students with disabilities: E-learning platforms should be designed with accessibility in mind to ensure inclusivity for students with disabilities. Features such as captioned videos, screen reader compatibility, and adjustable font sizes can facilitate the participation of students with diverse learning needs. Additionally, providing support services and resources tailored to the specific requirements of students with disabilities can further promote their engagement and success in online learning environments.

By implementing these practical recommendations, educational institutions can enhance the adoption and effectiveness of e-learning platforms in biology education. The integration of technology and pedagogy in a thoughtful and purposeful manner can create engaging and enriching learning experiences, ultimately benefiting students' academic achievement and fostering their interest and enthusiasm for biology.

7-2- Limitations

- Sample Representativeness: The study was conducted within a specific educational context, focusing on a single secondary school in the Turkestan region of Kazakhstan. Although the sample size was sufficient for the research objectives, the generalizability of the findings to a broader population may be limited. The participants were drawn from a specific school, and their characteristics, including grade levels and prior experiences, may not be fully representative of all educational settings.
- Contextual Factors: The study did not extensively explore contextual factors that could influence e-learning adoption and engagement, such as the quality of teaching, technical infrastructure, or external support systems. These contextual variables may interact with the factors examined in this study and could have implications for the interpretation of the results.
- Cultural Specificity: This study was conducted in a specific cultural and educational context in Kazakhstan. Cultural factors can significantly influence technology adoption and educational practices. Therefore, the findings may not fully generalize to different cultural or educational contexts without further cross-cultural validation.

Addressing these limitations in future research endeavors can contribute to a more comprehensive understanding of the factors affecting e-learning adoption and engagement, while also expanding the applicability of the findings to diverse educational settings.

8- Declarations

8-1- Author Contributions

Conceptualization, N.S. and G.I.; methodology, G.K.; software, S.A.; validation, A.B., K.B., and N.S.; formal analysis, N.S.; investigation, N.S.; resources, S.A.; data curation, G.K.; writing—original draft preparation, N.S.; writing—review and editing, S.A.; visualization, G.K.; supervision, S.A.; project administration, N.S.; funding acquisition, G.I. All authors have read and agreed to the published version of the manuscript.

8-2- Data Availability Statement

The data presented in this study are available in the present article.

8-3- Funding

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8-4- Institutional Review Board Statement

Not applicable.

8-5- Informed Consent Statement

Informed consent was obtained from all subjects involved in the study.

8-6- Conflicts of Interest

The authors declare that there is no conflict of interest regarding the publication of this manuscript. In addition, the ethical issues, including plagiarism, informed consent, misconduct, data fabrication and/or falsification, double publication and/or submission, and redundancies have been completely observed by the authors.

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