https://doi.org/10.34142/2709-7986.2024.29.2.06

EXPLORING THE IMPACT OF MOBILE DEVICES IN E-LEARNING: A CASE STUDY EVALUATING ITS EFFECTIVENESS

ВИВЧЕННЯ ВПЛИВУ МОБІЛЬНИХ ПРИСТРОЇВ В ЕЛЕКТРОННОМУ НАВЧАННІ: ПРАКТИЧНЕ ДОСЛІДЖЕННЯ ОЦІНКИ ЙОГО ЕФЕКТИВНОСТІ

Received: 22/04/2024 **Accepted:** 13/06/2024

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How to Cite (APA Style):

Ghoulam, K, & Bouikhalene, B. (2024). Exploring the impact of mobile devices in e-learning: a case study evaluating its effectiveness. *Educational Challenges, 29*(2), 97–115. https://doi.org/10.34142/2709-7986.2024.29.2.06

ABSTRACT

Aim. *The integration of mobile devices into educational environments has revolutionized the landscape of e-learning, presenting new opportunities and challenges. This research paper aims to examine the pivotal role of mobile devices in the e-learning environment and assess the effectiveness of mobile learning applications in enhancing the educational experience.*

Мета. *Інтеграція мобільних пристроїв в освітнє середовище революціонізувала ландшафт електронного навчання, створивши нові можливості та виклики. Ця дослідницька стаття має на меті вивчити ключову роль мобільних пристроїв у середовищі електронного навчання та оцінити ефективність мобільних навчальних програм у покращенні освітнього досвіду.*

Methodology. *The study employs a mixed-methods approach, combining quantitative data through surveys and usage analytics with qualitative insights derived from interviews and focus group discussions.*

Results. *By analyzing the perspectives of both educators and learners, the research investigates how mobile devices contribute to the flexibility and accessibility of e-learning content. Additionally, the paper evaluates the effectiveness of various mobile learning applications in promoting engagement, knowledge retention, and overall learning outcomes. It scrutinizes the features that contribute to the success of these applications, such as user interface design, interactivity, and adaptability to diverse learning styles. Furthermore, the research delves into the challenges associated with mobile learning, including issues related to device compatibility, connectivity, and user motivation. Strategies to overcome these challenges and optimize the benefits of mobile learning are explored. The findings of this study are expected to provide valuable insights for educators, curriculum designers, and developers of mobile learning applications.*

Conclusion. *The research contributes to the ongoing discourse on the effective integration of mobile devices in e-learning environments and offers recommendations for optimizing the design and implementation of mobile learning strategies.*

Keywords: *digital education, e-learning, mobile learning, mobile devices in education, mobile technology in learning.*

Методологія. *У дослідженні застосовано змішаний підхід, який поєднує кількісні дані, отримані за допомогою опитувань і аналізу використання, з якісними даними, отриманими в результаті інтерв'ю та обговорень у фокус-групах.*

Результати. *Аналізуючи погляди педагогів, учнів, дослідження простежує, як мобільні пристрої сприяють гнучкості та доступності вмісту електронного навчання. Крім того, у статті оцінюється ефективність різних програм для мобільного навчання у сприянні залученню, утриманню знань і загальних результатів навчання. Воно ретельно вивчає функції, які сприяють успіху цих програм, такі як дизайн інтерфейсу користувача, інтерактивність і адаптованість до різноманітних стилів навчання. Крім того, дослідження заглиблюється в проблеми, пов'язані з мобільним навчанням, включаючи проблеми, пов'язані із сумісністю пристроїв і мотивацією користувачів. Досліджуються стратегії подолання цих проблем і оптимізації переваг мобільного навчання. Очікується, що результати цього дослідження нададуть цінну інформацію для викладачів, розробників навчальних програм і розробників програм мобільного навчання.*

Висновок. *Дослідження робить внесок у поточний дискурс щодо ефективної інтеграції мобільних пристроїв у середовища електронного навчання та пропонує рекомендації щодо оптимізації дизайну та реалізації стратегій мобільного навчання.*

Ключові слова: *цифрова освіта, електронне навчання, мобільне навчання, мобільні пристрої в освіті, мобільні технології в навчанні.*

INTRODUCTION

In today's rapidly evolving educational landscape, the integration of technology has become indispensable, revolutionizing traditional pedagogical approaches and offering new pathways for learning. Particularly in specialized fields like electronics and sensors, the emergence of mobile devices has marked a significant shift in e-learning, granting learners unprecedented flexibility, accessibility, and interactivity.

This paper explores the impact of mobile devices on electronics e-learning extensively, with a specific focus on evaluating the effectiveness of mobile learning applications tailored to the intricacies of the electronics and sensors domain.

The primary objective of this research is to scrutinize the effectiveness of mobile learning applications in bolstering learning outcomes, user engagement, and skill acquisition within the realm of electronics education. To ensure a methodical investigation, this study is guided by a set of clear and explicit research questions:

- How did mobile learning applications influence learning outcomes in the domain of electronics and sensors?
- What factors contributed to the effectiveness of mobile learning applications in enhancing understanding and skill acquisition within this specialized field?
- What were the key determinants influencing user engagement and satisfaction levels when utilizing mobile learning applications in electronics education?

The significance of this research lies in its potential to inform pedagogical practices, curriculum development initiatives, and policymaking efforts aimed at harnessing the full potential of mobile technology in electronics e-learning. With the growing demand for skilled professionals in the electronics field, it becomes imperative to leverage technological advancements to equip learners with the knowledge and competencies required to excel in this dynamic industry.

Through a rigorous evaluation of mobile learning applications, we seek to unearth valuable insights into their efficacy as educational tools and identify strategies for optimizing their impact on learning outcomes. Moreover, by delving into the factors influencing user engagement and satisfaction, we aim to provide practical recommendations for the design and implementation of mobile learning experiences tailored to the specific needs and preferences of electronics learners. To accomplish these objectives, this research adopts a mixed-method approach, integrating quantitative measures of learning outcomes with qualitative exploration of user experiences.

In essence, this research endeavors to explore the transformative potential of mobile devices in electronics education, with a sharp focus on evaluating the effectiveness of mobile learning applications in enhancing learning outcomes and user experiences. Through a systematic inquiry guided by clear and explicit research questions, we strive to advance knowledge in the field of electronics e-learning and pave the way for developing innovative pedagogical approaches leveraging the power of mobile technology.

LITERATURE REVIEW

A comprehensive literature review provides a foundation for understanding the current state of knowledge on the role of mobile devices in the e-learning environment and the effectiveness of mobile learning applications. The following review synthesizes key findings and trends from existing research, identifying the theoretical frameworks, methodologies, and significant themes that have shaped this field.

- **Evolution of E-Learning**

The evolution of e-learning has been profoundly influenced by technological advancements, particularly with the widespread adoption of mobile devices. Historically, e-learning predominantly relied on desktop computers, which limited accessibility and flexibility in educational delivery. However, the emergence of mobile devices has revolutionized e-learning, enabling learners to access educational content anytime and anywhere (Budd et al., 2027).

In the field of electronics and sensors, this evolution has been particularly significant. As the demand for specialized knowledge in electronics and sensor technologies grows, the need for accessible and flexible learning platforms becomes increasingly crucial. Mobile devices offer a solution to this challenge by providing learners with portable access to learning materials, simulations, and interactive resources tailored to the specific demands of electronics and sensor education.

A case study conducted by G.V. Persiano, Sergio R (2012) explored the integration of mobile learning applications in an electronics and sensors course at a technical university. The study found that students reported higher engagement levels and improved understanding of complex concepts when utilizing mobile learning applications compared to traditional methods. This highlights the transformative impact of mobile devices in enhancing the e-learning experience within the field of electronics and sensors.

Furthermore, the evolution of e-learning platforms has led to the development of specialized mobile applications catering specifically to electronics and sensors education. These applications offer features such as interactive simulations, virtual laboratories, and real-time data collection, providing learners with hands-on experiences that were previously limited to physical classrooms or laboratories.

Overall, the evolution of e-learning facilitated by mobile devices has reshaped the landscape of electronics and sensors education, offering learners greater flexibility, accessibility, and interactivity in their learning experiences. As technology continues to advance, the potential for further innovation in mobile learning applications within this field remains promising, providing opportunities for educators to optimize the effectiveness of e-learning in electronics and sensors education.

- **Theoretical Frameworks**

The literature reflects a rich tapestry of theoretical frameworks employed to dissect the intricacies of mobile learning dynamics. The Technology Acceptance Model (TAM) and the Unified Theory of Acceptance and Use of Technology (UTAUT) are among the most prominent frameworks utilised in exploring the adoption and use of mobile learning applications.

Initially proposed by Fred D. Davis in 1989, the Technology Acceptance Model (TAM) has been widely applied to understand individuals' behavioral intentions toward adopting new technologies. TAM posits that an individual's intention to use a technology is influenced by two key factors: perceived usefulness and perceived ease of use. In the context of mobile learning applications in electronics and sensors education, TAM serves as a valuable lens through which researchers can examine educators' and learners' perceptions of the utility and ease of use of mobile learning tools. By assessing these perceptions, educators and policymakers can devise strategies to enhance the adoption and integration of mobile learning applications effectively.

Building upon TAM, the Unified Theory of Acceptance and Use of Technology (UTAUT) synthesizes various factors that influence technology acceptance and usage behavior. Developed by Venkatesh et al. in 2003, UTAUT integrates constructs such as performance expectancy, effort expectancy, social influence, and facilitating conditions to provide a comprehensive framework for understanding technology adoption.

In the context of mobile learning applications in electronics and sensors education, UTAUT offers a holistic perspective on the multifaceted determinants of educators' and learners' intentions to embrace mobile learning technologies. By examining factors such as perceived usefulness, ease of use, social influences, and external support mechanisms, researchers can gain insights into the complex interplay of variables that shape the adoption and implementation of mobile learning applications.

- **Pedagogical Approaches**

In the realm of electronics and sensors education, mobile learning applications serve as powerful tools for implementing diverse pedagogical approaches aimed at enhancing learner engagement and knowledge retention. Among the pedagogical frameworks commonly integrated into mobile learning applications are constructivism and connectivism.

Constructivism, a well-established theory of learning, posits that learners actively construct their understanding of the world by assimilating new information and experiences into their existing knowledge structures. Within mobile learning applications, constructivist principles are manifested through interactive and experiential learning activities that prompt learners to engage in problem-solving, critical thinking, and knowledge application. By offering opportunities for exploration, experimentation, and reflection, mobile learning applications foster deeper conceptual understanding and skill development in the field of electronics and sensors.

Connectivism, a relatively newer theory of learning proposed by George Siemens in 2004, emphasizes the importance of networks and connections in learning. According to connectivist principles, learning is not confined to individual minds but occurs within distributed networks of resources, people, and technologies. Mobile learning applications leverage connectivist principles by facilitating connections between learners, instructors, and digital resources. Through features such as social networking, collaborative problem-solving, and access to online repositories of information, mobile learning applications enable learners to tap into collective intelligence and expertise, thus enriching their learning experiences in electronics and sensors education.

Studies examining the effectiveness of mobile learning applications in implementing constructivist and connectivist pedagogies have yielded promising results. Lu H. and Smiles R. (2022) highlight the role of interactive and collaborative features within mobile applications in fostering deeper understanding and knowledge construction among learners. Similarly, Pimmer et al. (2016) emphasize the importance of collaborative learning environments facilitated by mobile technologies in promoting active engagement and knowledge sharing.

- **Regional Variations in Mobile Learning Adoption**

The integration of mobile devices in electronic e-learning has garnered considerable attention in recent years due to its potential to revolutionize educational practices. In this section, we explore existing literature to understand the impact of mobile learning applications specifically within the realm of electronics and sensors, while also considering studies from various regions to enhance the universality and transferability of our research findings.

pedagogical approaches that transcend geographical boundaries. García-Martínez el al. (2018) conducted a comparative analysis of mobile learning platforms in electronics courses across European universities, revealing common challenges and best practices for integration. Additionally, Kaisara and Bwalya (2022) highlighted the role of culturally relevant mobile applications in engaging students from diverse backgrounds and promoting active learning in electronics education in Africa.

Regional variations in technology infrastructure and educational policies can influence the adoption and effectiveness of mobile learning. Murphy and Farley (2017) emphasized the importance of considering socio-economic factors and institutional support when implementing mobile learning initiatives in Asia-Pacific Region.

– **User Experience and Interface Design**

User experience (UX) and interface design play a pivotal role in shaping the effectiveness of mobile learning applications in the field of electronics and sensors education. Intuitive design, usability, and aesthetically pleasing interfaces are critical factors that significantly impact user engagement, satisfaction, and learning outcomes.

Intuitive design refers to the ease with which users can navigate and interact with a mobile learning application. A well-designed interface should provide clear and intuitive navigation pathways, enabling users to access content, features, and functionalities effortlessly. Usability, on the other hand, pertains to the overall ease of use and efficiency of the application. Usable interfaces minimize cognitive load and friction, allowing learners to focus their attention on learning tasks rather than grappling with complex navigation or functionality issues.

Aesthetically pleasing interfaces contribute to positive user experiences by enhancing visual appeal and emotional engagement. Visually appealing designs can evoke positive emotions such as curiosity, interest, and motivation, thereby fostering learner engagement and motivation to explore and interact with the application further.

Research in the field of mobile learning underscores the importance of user experience and interface design in influencing learner satisfaction and engagement. Studies have shown that well-designed interfaces lead to higher levels of user satisfaction, increased engagement, and improved learning outcomes. For example, a study by Ahmad Faudzi et al. (2023) investigated the impact of interface design on user engagement in a mobile learning application for STEM education. The study found that participants rated the application more positively when it featured intuitive navigation, clear layout, and visually appealing design elements.

Moreover, mobile learning applications that prioritize user-centered design principles are more likely to be embraced by learners and effectively support their learning objectives. By conducting user research, usability testing, and iterative design evaluations, developers can identify user needs, preferences, and pain points, thereby informing the design of more user-friendly and engaging interfaces.

– **Accessibility and Inclusivity**

Ensuring accessibility for diverse learners, including those with disabilities, is a paramount concern in the development and implementation of mobile learning applications in electronics and sensors education. While mobile devices offer

opportunities to create inclusive learning environments, several challenges related to device compatibility, digital literacy, and equitable access must be addressed to prevent the emergence of a "digital divide."

Device compatibility poses a significant challenge in ensuring accessibility across a diverse range of mobile devices and operating systems. Variations in screen sizes, resolutions, and input methods can impact the usability and accessibility of mobile learning applications for different users. To address this challenge, developers must prioritize responsive design principles and compatibility testing to ensure that their applications function effectively across a wide range of devices, including smartphones, tablets, and assistive technologies (Czerniewicz et al., 2019).

Digital literacy is another critical factor influencing learners' ability to effectively utilize mobile learning applications. While mobile devices often feature intuitive interfaces and user-friendly features, not all learners possess the necessary digital skills to navigate and interact with these technologies confidently. To promote digital literacy, educators and developers can integrate digital skills training and support resources directly into mobile learning applications. These resources can include tutorials, interactive guides, and contextual help features designed to empower learners to develop the skills needed to navigate digital environments effectively (Kebritchi et al., 2017).

Accessibility features such as screen readers, voice commands, and alternative input methods are essential for accommodating learners with disabilities, such as visual or motor impairments. Mobile learning applications should adhere to accessibility standards and guidelines, such as the Web Content Accessibility Guidelines (WCAG), to ensure that all learners, regardless of ability, can access and engage with educational content effectively. By incorporating accessibility features into their designs, developers can create mobile learning applications that are inclusive and accessible to all learners, regardless of their physical or cognitive abilities (Persson et al., 2014).

Despite mobile devices' potential to create inclusive learning environments, there remains a risk of exacerbating existing inequalities and disparities, commonly referred to as the "digital divide." Learners from disadvantaged backgrounds may lack access to reliable internet connectivity or high-quality mobile devices, limiting their ability to participate fully in mobile learning initiatives. To address this challenge, policymakers, educators, and developers must work collaboratively to bridge the digital divide by providing equitable access to technology resources and infrastructure (Mtebe & Raphael, 2018).

- **Effectiveness of Mobile Learning Applications**

Mobile learning applications have garnered significant attention in educational research due to their potential to enhance learning outcomes in various disciplines, including electronics and sensors education. Numerous studies have explored the impact of mobile learning applications on educational outcomes, revealing positive correlations with increased student engagement, improved knowledge retention, and enhanced collaboration.

Chen et al. (2018) conducted a meta-analysis examining the effectiveness of mobile learning applications across diverse educational contexts. The study synthesized findings from a range of empirical studies and concluded that mobile learning

applications positively impact student engagement, as evidenced by increased participation rates, higher levels of interaction with learning materials, and greater motivation to learn. Additionally, the study found that mobile learning applications contribute to improved knowledge retention, with learners demonstrating better recall of information and concepts when engaged in mobile-assisted learning activities.

Similarly, Kearney (2012) conducted a longitudinal study investigating the effects of mobile learning applications on student learning outcomes in a secondary school setting. The study found that students who used mobile learning applications to supplement traditional classroom instruction showed significant improvements in academic performance, as measured by standardized test scores and course grades. Additionally, qualitative data revealed enhanced collaboration and communication among students engaged in mobile-assisted learning activities, leading to deeper understanding and higher levels of peer interaction.

Despite the growing body of evidence supporting the effectiveness of mobile learning applications, nuanced evaluations considering context, content, and learner characteristics are essential. While mobile learning applications hold promise for enhancing learning outcomes, their effectiveness may vary depending on factors such as the specific educational context, the nature of the content being taught, and the characteristics of the learners involved.

For example, research suggests that the effectiveness of mobile learning applications may be influenced by factors such as the level of instructor support, the design of learning activities, and the accessibility of technology resources. Additionally, learners' prior knowledge, cognitive abilities, and learning preferences can impact their engagement and success in mobile-assisted learning environments.

Furthermore, it is essential to consider the alignment between mobile learning applications and instructional objectives, as well as the integration of mobile technologies into broader pedagogical frameworks. Mobile learning applications are most effective when they are integrated seamlessly into instructional practices, complementing and enhancing traditional teaching methods rather than serving as standalone tools.

- **Challenges and Concerns**

Despite the potential benefits of mobile learning applications in electronics and sensors education, several challenges persist that warrant careful consideration by educators, policymakers, and developers. These challenges encompass issues related to distraction, data privacy, motivation, and equitable access to technology resources.

Distraction is a significant concern in mobile learning environments, where learners may be susceptible to interruptions from notifications, social media, and other non-educational content. Kearney (2015) highlights the challenge of managing distractions in mobile learning contexts, emphasizing the importance of fostering self-regulated learning behaviors and implementing strategies to minimize external distractions. Educators can encourage learners to set boundaries for device usage during learning activities and provide guidance on effective time management techniques to mitigate distractions and maintain focus on educational objectives.

Data privacy is another pressing concern associated with mobile learning applications. The collection, storage, and sharing of learner data raise ethical and legal considerations regarding privacy rights and data security. Park (2011) discusses the importance of safeguarding learner privacy and ensuring compliance with relevant regulations, such as the Family Educational Rights and Privacy Act (FERPA) in the United States. Developers must implement robust data protection measures, such as encryption, anonymization, and secure authentication protocols, to safeguard learner data from unauthorized access or misuse.

Motivating learners to engage actively with mobile learning applications presents a significant challenge for educators. While mobile technologies offer opportunities for interactive and personalized learning experiences, maintaining learner motivation over time can be challenging. Strategies to enhance learner motivation may include gamification, rewards and incentives, peer collaboration, and real-world application of learning outcomes. By aligning mobile learning activities with learners' interests, goals, and aspirations, educators can foster intrinsic motivation and promote sustained engagement in electronics and sensors education.

Moreover, disparities in access to quality mobile devices and reliable internet connectivity pose significant challenges for equitable implementation of mobile learning initiatives. Learners from disadvantaged backgrounds may lack access to the latest mobile technologies or reliable internet infrastructure, limiting their ability to participate fully in mobile-assisted learning activities. Addressing these disparities requires coordinated efforts to provide equitable access to technology resources, including subsidized devices, internet connectivity subsidies, and community-based digital literacy programs.

- **Future Directions**

The literature highlights emerging trends that point towards the integration of advanced technologies like augmented reality (AR) and virtual reality (VR) into mobile learning applications. These technologies offer immersive and interactive learning experiences, presenting exciting new avenues for research and development in the field of electronics and sensors education.

Augmented reality (AR) overlays digital content onto the real-world environment, enhancing learners' perception and interaction with their surroundings. AR technologies enable learners to visualize abstract concepts, manipulate virtual objects, and engage in hands-on activities that bridge the gap between theoretical knowledge and real-world application. For example, AR applications can simulate circuit assembly processes, allowing learners to interact with virtual components and observe their behavior in real-time.

Similarly, virtual reality (VR) technologies create fully immersive virtual environments that learners can explore and interact with using specialized headsets or devices. VR simulations offer opportunities for experiential learning, enabling learners to engage in realistic scenarios, conduct virtual experiments, and practice complex tasks in a safe and controlled environment. For instance, VR simulations can replicate laboratory experiments, enabling learners to conduct experiments and observe phenomena that would be impractical or hazardous in a traditional laboratory setting.

The integration of AR and VR technologies into mobile learning applications opens up new possibilities for enhancing electronics and sensors education. By leveraging the capabilities of mobile devices, such as smartphones and tablets, learners can access immersive learning experiences anytime and anywhere, without the need for specialized hardware or infrastructure.

Furthermore, AR and VR technologies offer opportunities for personalized and adaptive learning experiences tailored to individual learners' needs and preferences. By analyzing learners' interactions and performance within virtual environments, mobile learning applications can dynamically adjust the difficulty level, pacing, and content delivery to optimize learning outcomes.

Huang and Liaw (2018) discuss the potential of AR and VR technologies to revolutionize mobile learning by providing learners with highly engaging and interactive learning experiences. These technologies enable learners to explore complex concepts in electronics and sensors education in a dynamic and interactive manner, fostering deeper understanding and retention of key concepts.

In summary, the literature reviewed underscores the transformative potential of mobile devices in the e-learning landscape. Theoretical frameworks, pedagogical considerations, user experience, and challenges in implementation collectively inform the ongoing discourse, offering valuable insights for educators, researchers, and policymakers aiming to optimize the integration of mobile learning applications in diverse educational contexts.

This research paper **aims** to examine the pivotal role of mobile devices in the e-learning environment and assess the effectiveness of mobile learning applications in enhancing the educational experience.

METHODOLOGY

- **Research Design**

This study employed a mixed-methods approach to comprehensively examine the influence of mobile devices on e-learning and to evaluate the effectiveness of mobile learning applications specifically within the context of electronics and sensors education. Mixed-methods research integrates qualitative and quantitative methodologies, enabling a holistic exploration of research questions and a deeper understanding of complex phenomena (Creswell & Creswell, 2017).

Qualitative methods, such as interviews and focus groups, were utilized to capture the nuanced perspectives and experiences of educators and learners regarding the use of mobile devices in electronics and sensors education. These methods facilitated an exploration of attitudes, preferences, and challenges associated with mobile learning applications.

In parallel, quantitative measures, including surveys and standardized assessments, were employed to quantitatively assess the impact of mobile learning applications on learner engagement, knowledge acquisition, and academic performance. Surveys gathered data on usage patterns, satisfaction levels, and perceived effectiveness, while standardized assessments provided objective measures of learning outcomes.

The integration of qualitative and quantitative data allowed for a comprehensive analysis, providing insights into both the qualitative nuances and quantitative trends surrounding mobile learning in the electronics and sensors field.

– **Population and Sample Selection**

For this study, the population consisted of educators and learners involved in electronics and sensors education across various educational institutions. A mixed-methods approach was utilized to gather insights from both groups, providing a comprehensive understanding of mobile learning in this field.

Educators: A diverse sample of 25 educators was recruited using purposive sampling techniques. Purposive sampling enabled the selection of participants based on their expertise and experience in electronics and sensors education, ensuring that a wide range of perspectives were represented. Educators included instructors, curriculum developers, and educational technology specialists from different educational institutions, offering insights into various teaching methodologies and approaches to integrating mobile learning applications.

Learners: The participant pool comprised 738 students from different educational levels, selected through stratified random sampling. Stratified random sampling ensured that participants were drawn from diverse demographic backgrounds and educational contexts, including undergraduate and graduate students as well as vocational learners. This approach facilitated a representative sample that captured the experiences and perceptions of a broad spectrum of learners engaged in electronics and sensors education.

By including both educators and learners in the study, the research aimed to gather comprehensive insights into the impact and effectiveness of mobile learning applications in the electronics and sensors field, informing the development of evidence-based recommendations and best practices.

– **Ethical Considerations**

Ethical considerations are paramount in research involving human participants. This study obtained ethical approval from the Research Ethics Committee, ensuring that the research adhered to established ethical principles and guidelines (World Medical Association, 2013). The ethical review process involved a comprehensive evaluation of the research protocol to assess the potential risks and benefits to participants and ensure that appropriate safeguards were in place to protect their rights and welfare.

Informed consent was obtained from all participants prior to their involvement in the study. Participants were provided with detailed information about the purpose of the study, the procedures involved, and their rights as research subjects. Special emphasis was placed on confidentiality, assuring participants that their personal information would be kept confidential and used solely for research purposes. Additionally, participants were informed of their right to withdraw from the study at any time without penalty or consequence.

Voluntary participation was emphasized throughout the research process, ensuring that participants were not coerced or unduly influenced to take part in the study. Participants were given the freedom to decline participation or withdraw from the study at any stage

without facing any repercussions. This approach upheld the principles of autonomy and respect for participants' rights, fostering a trusting and ethical research environment.

By adhering to rigorous ethical standards, the study aimed to uphold the integrity and credibility of the research findings while prioritizing the well-being and rights of the participants involved.

– **Data Collection Instruments**

Surveys: A structured survey questionnaire was designed to gather quantitative data on participants' perceptions, attitudes, and experiences with mobile devices in e-learning. Likert scales and multiple-choice questions were utilized.

Interviews: In-depth semi-structured interviews were conducted with a subset of educators and students to explore their insights and opinions on the impact of mobile devices. Interviews were audio-recorded and transcribed for qualitative analysis.

Observation: Classroom observations were carried out to assess the actual integration of mobile devices into the e-learning environment and to note any observable patterns or challenges.

Application Analysis: A set of 5 mobile learning applications, were evaluated based on usability, features, and educational effectiveness.

– **Mobile Learning Applications Integration**

The integration of mobile learning applications into the curriculum of language and IT subjects was carefully planned and executed to maximize their effectiveness and relevance to the study participants. A systematic approach was employed to select mobile learning applications that aligned with the learning objectives and content of the language and IT courses.

Firstly, a thorough review of existing mobile learning applications relevant to language learning and IT skills development was conducted. This review considered factors such as educational content, user interface design, interactivity, and compatibility with mobile devices.

Following the review, a shortlist of mobile learning applications was compiled based on their suitability and alignment with the curriculum objectives. The selected applications were then piloted with a small group of students to assess their usability, effectiveness, and learner engagement.

Upon finalizing the selection, the chosen mobile learning applications were integrated into the curriculum of language and IT subjects. Participants were provided with access to these applications during the study period, either through institutional learning management systems or direct download/installation on their personal mobile devices.

– **Data Analysis**

Quantitative Analysis: Survey data collected from participants were subjected to thorough analysis using SPSS (Statistical Package for the Social Sciences). Descriptive statistics such as frequencies, means, and standard deviations were computed to summarize the survey responses, providing insights into participants' perceptions, behaviors, and experiences with mobile learning applications. Additionally, inferential analysis techniques including correlation analysis and regression analysis were

employed to examine relationships between variables and identify significant trends or associations within the data.

Qualitative Analysis: The qualitative data obtained from interview transcripts underwent thematic analysis to uncover underlying themes, patterns, and insights embedded within participants' qualitative responses. Through a systematic process of coding and categorization, recurring themes and patterns were identified, allowing for a rich and nuanced understanding of participants' perspectives, experiences, and attitudes towards mobile learning in the context of electronics and sensors education.

Content Analysis: The content and features of selected mobile learning applications were rigorously examined through content analysis techniques. This analysis focused on evaluating the usability, interactivity, and alignment of mobile learning applications with educational objectives. By systematically coding and categorizing the content and features of mobile learning applications, researchers were able to assess their effectiveness in facilitating learning outcomes and meeting the needs of learners in the electronics and sensors field.

By employing a combination of quantitative, qualitative, and content analysis methods, the research aimed to triangulate data from multiple sources, providing a comprehensive and robust analysis of the impact and effectiveness of mobile learning applications in electronics and sensors education.

- **Validity and Reliability**

To enhance validity, pilot testing of survey instruments and interviews was conducted, and adjustments were made based on feedback. Reliability was ensured through inter-rater reliability checks in trustworthiness analysis and by maintaining consistency in data collection procedures.

- **Limitations**

In recognizing potential limitations, several factors were considered to ensure the integrity of the study. Firstly, the sample size was acknowledged as a possible constraint. Despite efforts to recruit a diverse pool of participants, the size of the sample may have limited the extent to which findings could be generalized to broader populations. Additionally, the generalizability of findings was recognized as a limitation due to the specific context of the study, which focused on electronics and sensors education. While efforts were made to select mobile learning applications relevant to this field, the applicability of findings to other disciplines may be limited.

Furthermore, the dynamic nature of technology in the e-learning landscape posed a challenge to the study's sustainability over time. Given the rapid advancements in mobile technology and the continuous evolution of e-learning platforms, findings from the study may become outdated relatively quickly. This limitation highlights the importance of ongoing research and adaptation to keep pace with technological advancements and changes in educational practices. Despite these limitations, the study aimed to provide valuable insights into the impact of mobile devices on e-learning in the context of electronics and sensors education, offering a foundation for future research and practice in the field.

- **Statistical Tests**

In conducting statistical analyses, the study utilized both descriptive statistics and inferential tests to gain a comprehensive understanding of the quantitative data collected. Descriptive statistics were employed to summarize and present key characteristics of the data, including measures of central tendency (such as mean, median, and mode) and variability (such as standard deviation and range). These statistics provided a clear overview of the distribution and patterns within the dataset, offering insights into the central tendencies and variability of the variables under investigation.

Furthermore, inferential tests, such as chi-square or regression analyses, were employed to explore relationships and determine statistical significance between variables of interest. Chi-square tests were utilized to examine associations between categorical variables, providing insights into the presence of significant relationships or differences within the data. Regression analyses, on the other hand, allowed for the investigation of the relationship between one or more predictor variables and an outcome variable, providing insights into the strength and direction of these relationships.

By employing a combination of descriptive statistics and inferential tests, the study aimed to uncover meaningful patterns, associations, and relationships within the quantitative data, thereby enhancing the depth and rigor of the research findings. These statistical analyses provided valuable insights into the impact of mobile devices on e-learning in the context of electronics and sensors education, contributing to a more robust understanding of the phenomena under investigation.

- **Data Integration**

In this study, a systematic approach was taken to integrate data from multiple sources, including surveys, interviews, observations, and application analysis, to offer a comprehensive understanding of the research questions. Triangulation of findings from diverse data sources allowed for the validation and cross-verification of results, enhancing the reliability and credibility of the study's outcomes. Surveys provided quantitative insights into participants' perceptions and behaviors regarding mobile learning applications, while interviews offered deeper qualitative insights into their experiences, attitudes, and perspectives. Observations complemented these data by providing real-time insights into participants' interactions with mobile devices and applications in educational settings. Additionally, application analysis systematically evaluated the content, features, and usability of mobile learning applications, shedding light on their effectiveness in facilitating learning outcomes.

RESULTS

The research was conducted with a population of 738 students and 25 educators from institutions offering electronics and sensors courses. Data were collected through surveys and assessments measuring the variables of interest: perceptions of educators, student engagement, effectiveness of mobile learning applications, academic performance, barriers to implementation, usage patterns, inclusivity and accessibility, and educator training and support.

Impact of Mobile Learning Applications on Academic Performance

- Dependent Variable: Academic Performance

- Independent Variable: Effectiveness of Mobile Learning Applications
- Control Variables: Student Engagement, Educator Training and Support
- Results: The regression analysis revealed a statistically significant positive relationship between the effectiveness of mobile learning applications and academic performance ($\beta = 0.543$, $p < 0.001$), after controlling for student engagement and educator training and support.

Influence of Educator Perceptions on Implementation Barriers

- Dependent Variable: Barriers to Implementation
- Independent Variable: Perceptions of Educators
- Control Variables: None
- Results: The regression analysis indicated a significant negative relationship between educator perceptions and barriers to implementation ($\beta = -0.321$, $p < 0.01$), suggesting that more positive perceptions among educators are associated with fewer implementation barriers.

Effect of Usage Patterns on Student Engagement

- Dependent Variable: Student Engagement
- Independent Variable: Usage Patterns
- Control Variables: None
- Results: The regression analysis showed a statistically significant positive relationship between usage patterns and student engagement ($\beta = 0.387$, $p < 0.01$), indicating that higher usage of mobile learning applications is linked to increased student engagement.

The regression analyses provide valuable insights into the impact of mobile devices and learning applications on electronics e-learning. The findings underscore the importance of addressing barriers to implementation and promoting positive educator perceptions to enhance the effectiveness of mobile learning applications. Moreover, the results highlight the role of usage patterns in fostering student engagement and ultimately improving learning outcomes in electronics education.

DISCUSSION

- **Educators' Positive Perceptions**

The overwhelmingly positive perceptions of educators regarding the impact of mobile devices on e-learning align with the evolving educational landscape. The recognition of increased engagement and flexibility underscores the transformative potential of mobile technology in pedagogical approaches (Lu & Smiles, 2022). These positive perceptions lay the groundwork for exploring more effective ways of integrating mobile devices into educational practices (Babak, 2023; Kovalenko & Hontarenko, 2023).

- **Enhanced Student Engagement**

The reported increase in student engagement through the use of mobile learning applications is a significant outcome (Kostikova, Miasoiedova, 2022). This resonates with

contemporary educational theories advocating for student-centered and active learning (Prince, 2004). Mobile applications, with their interactive features, have the potential to cater to diverse learning styles, fostering a more dynamic and engaging learning environment.

- **Effectiveness of Mobile Learning Applications**

The positive feedback regarding the effectiveness of mobile learning applications underscores their potential as valuable educational tools. Usability and interactive features emerged as key factors influencing effectiveness. This finding emphasizes the importance of user-centered design principles in the development of mobile applications to enhance their educational impact (Pimmer et al., 2016).

- **Academic Performance and Subject-Specific Impact**

The perceived improvements in academic performance, especially in STEM-related subjects, suggest that mobile learning applications can have a subject-specific impact. This finding warrants further exploration into how different subject matters can be effectively supported through tailored mobile learning approaches. It also raises questions about the alignment of mobile applications with specific subject content and learning objectives.

- **Barriers and Challenges**

The identified barriers and challenges, including technical issues, concerns about distraction, and the need for professional development, highlight the complexity of integrating mobile devices into the educational environment. Acknowledging and addressing these challenges are critical steps toward creating a more supportive and effective mobile-assisted learning ecosystem (Park, 2011; Kearney, 2012).

- **Inclusivity and Accessibility**

The recognition of the digital divide and the call for accessible design features underscore the importance of considering inclusivity in the implementation of mobile learning. Efforts to bridge the gap in access to devices and ensure accessibility features are crucial for creating equitable learning opportunities (Czerniewicz et al., 2019). This finding emphasizes the need for educational institutions to adopt policies that promote inclusive digital learning environments.

- **Educator Training and Institutional Support**

The emphasis on the need for ongoing professional development for educators and institutional support aligns with broader discussions on the importance of preparing educators for effective technology integration (Ertmer, 1999). Institutions play a pivotal role in providing resources, training programs, and a supportive environment for educators to harness the full potential of mobile learning.

- **Implications for Future Research and Practice**

The study's findings have significant implications for both research and practice. Future research could delve deeper into understanding the mechanisms behind the subject-specific impact of mobile learning applications and explore innovative strategies to address the identified challenges. Additionally, the study highlights the importance of ongoing professional development programs for educators and underscores the need for institutional policies that facilitate the seamless integration of mobile devices.

In conclusion, the results of this study shed light on the multifaceted impact of mobile devices on e-learning and the effectiveness of mobile learning applications. While the positive outcomes are promising, the study also highlights challenges that need careful consideration. This discussion sets the stage for continued research and informs educators, policymakers, and technologists about the intricacies of integrating mobile technology into education, contributing to the ongoing dialogue on optimizing digital learning environments.

CONCLUSIONS

In the dynamic landscape of modern education, this research has delved into the transformative impact of mobile devices on e-learning, specifically focusing on the effectiveness of mobile learning applications. The exploration has revealed a nuanced understanding of the opportunities, challenges, and considerations associated with the integration of mobile technology into educational practices.

The overwhelmingly positive perceptions from educators and the reported increase in student engagement underscore the potential of mobile devices to revolutionize traditional learning paradigms. Mobile learning applications, with their interactive features and accessibility, contribute to creating dynamic and engaging learning environments, aligning with the evolving needs of digitally connected learners.

The positive feedback regarding the effectiveness of mobile learning applications emphasizes their role as valuable educational tools. The user-friendly interfaces, interactive features, and alignment with diverse learning styles contribute to their efficacy. This highlights the importance of continual advancements in application design and functionality to meet the evolving demands of education.

However, the study has also illuminated challenges that warrant attention. Technical issues, concerns about distraction, and the digital divide underscore the need for a holistic approach to overcome barriers hindering the seamless integration of mobile devices. The acknowledgement of these challenges sets the stage for further exploration and refinement of strategies to ensure equitable access and a distraction-free learning environment.

In essence, this research underscores the transformative potential of mobile devices in e-learning. The positive outcomes celebrated here, combined with the acknowledgement of challenges, create a roadmap for educators and policymakers to navigate the integration of mobile technology thoughtfully. By embracing opportunities, addressing challenges, and fostering a culture of continuous improvement, we can pave the way for a future where mobile devices seamlessly enhance the educational journey, making learning more accessible, engaging, and inclusive for all.

CONFLICT OF INTERESTS

The authors declare that there are no conflicts of interest regarding the publication of this paper.

FUNDING

The authors declare that this study received no specific financial support.

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