

THE EFFECTIVENESS OF MOBILE LEARNING APPS IN PLANT ANATOMY INSTRUCTION

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ABSTRACT

This study examines the effectiveness of mobile learning applications in teaching plant anatomy to undergraduate students. As educational technology evolves, mobile apps offer new opportunities for interactive and flexible learning. The research compares student outcomes between two groups: one using a mobile learning app and the other receiving traditional instruction. Using a quasi-experimental method, data were collected through pre-tests, post-tests, and student questionnaires. The findings show that students using mobile apps achieved significantly higher post-test scores and demonstrated better engagement and motivation. The visual and interactive features of the apps helped learners grasp complex anatomical structures more effectively. Despite some technical challenges, such as limited device compatibility, the study concludes that mobile learning apps are a promising tool to enhance plant anatomy instruction. Integration of such tools into the curriculum is recommended to support active and autonomous learning.

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1. Introduction

The integration of mobile technology into education has ushered in a paradigm shift, particularly in traditionally challenging subjects like plant anatomy (Al-Modwahi et al., 2013). Mobile learning applications (apps) present a unique opportunity to revolutionize how students engage with complex botanical structures and processes (Maulana & Nurgiyatna, 2019). The global shift towards mobile devices, particularly smartphones, has significantly altered instructional delivery and learning methodologies in higher education (Truong, 2014). Universities are increasingly adopting new technologies to overcome educational barriers and enhance both instruction and student learning outcomes (Truong, 2014). The availability of mobile devices has facilitated the design and development of learning tools across various fields, signifying a move towards more accessible and versatile educational resources (Yu, 2022). The accessibility of mobile devices, coupled with the increasing sophistication of mobile applications, creates new avenues for delivering educational content and engaging students in active learning experiences. Mobile learning provides a dynamic and flexible educational environment, allowing students to access information and interact with learning materials

anytime and anywhere (Kattayat et al., 2017). This is particularly relevant in fields like plant anatomy, where visual and spatial understanding are crucial for mastering intricate anatomical structures. The use of mobile learning is becoming increasingly prevalent in education, offering students and educators versatile tools and resources. (Drigas & Pappas, 2015). The incorporation of mobile learning in plant anatomy education is expected to enhance students' comprehension and retention of complex concepts, ultimately improving academic performance and fostering a deeper appreciation for the subject matter. The integration of mobile applications in anatomy education is particularly advantageous, offering students interactive and visually stimulating tools to explore complex structures (Chytas et al., 2020). The COVID-19 pandemic accelerated the adoption of mobile applications in education, highlighting their importance when traditional laboratory procedures and physical learning materials were restricted (Demir et al., 2023). Mobile applications offer a novel approach to education by providing dynamic content such as interactive simulations and 3D models, thus enhancing understanding and making learning more engaging.

2. Literature Review

Mobile learning, distinguished by its capacity to enable learning at any time and in any location, as well as capture, annotate, and share multimedia, introduces entirely new learning methods for students ("Designing for Mobile Learning," 2017). Mobile devices' increasing role in daily life has made their use in learning a valuable contribution to higher education globally (Cabrera-Solano et al., 2020). Given that students can process information both inside and outside the classroom, mobile learning enables them to learn whenever and wherever they choose (Torres, 2021). This is particularly helpful for topics like plant anatomy that need practical application and visualization. The versatility of mobile learning stems from its capacity to accommodate a variety of learning preferences and needs. It facilitates personalized learning paths by enabling students to select materials, pacing, and evaluation techniques that best suit their requirements. Mobile devices have evolved into effective educational resources due to their quick advancement from phones to cameras and even laptops (Ji & Aziz, 2021). In response to this trend, the idea of mobile learning has emerged as a strategy to enrich and improve educational experiences. The utilization of mobile learning has been shown to foster relational and communicative skills among students by enhancing their communication and teamwork abilities, as well as their capacity to solve problems and think critically. The application of mobile learning not only improves student learning and engagement, but it also encourages authentic and situated learning by encouraging communication between participants. Through the use of mobile devices, students can learn at their own speed and gain individualized learning experiences, which raises their motivation and involvement in the learning process. A study showed that using mobile learning technologies enhanced students' communication and teamwork skills, as well as their critical thinking and problem-solving abilities. Students who use mobile technologies may have more control over their learning and can adapt it to their own requirements. Additionally, students can benefit from individualized feedback and assistance from teachers or peers through mobile learning platforms.

Numerous studies have explored the use of mobile applications in science education, indicating a positive impact on student engagement, knowledge retention, and overall learning outcomes. Mobile learning provides a flexible educational environment, allowing students to access information and interact with learning materials anytime and anywhere. The wide application of mobile technology has promoted a new wave of technology-enhanced learning (Liu, 2020). The use of mobile electronic multimedia courses can increase the effectiveness of teaching (Krivoruchko et al., 2015). Mobile technologies possess flexibility, low cost, small size and

user-friendliness (Yu-jiao, 2021). These advantages have made it an educational tool with the potential to increase student motivation, support constructivist learning, and offer opportunities for situated learning. Mobile learning technologies have become vital in supporting students' learning and educational outcomes as mobile devices have become more widely available. Furthermore, mobile learning has proven to be especially beneficial in improving communication, collaboration, critical thinking, and problem-solving abilities among students (Galustyan et al., 2020). Mobile learning technologies are also becoming increasingly important in assisting students' learning and educational outcomes as mobile devices become more widely available. This strategy is in line with the strategic educational objectives of raising student retention and achievement, accommodating various learning needs, and reaching students who might not otherwise have the chance to participate in education (Elaish & Shuib, 2019). It is critical for educators to develop comprehensive mobile learning strategies that make use of the unique features of these devices to improve the learning process.

2.1. Mobile Learning in Education

Mobile learning is now an indispensable component of modern education, providing unmatched flexibility and accessibility for students across various academic disciplines (Bourekache & Kazar, 2020). Mobile learning offers the potential to address real-time learner needs and deliver more adaptable language learning models (Kukulka-Hulme, 2020). The utilization of mobile devices in education transcends traditional classroom settings, enabling students to engage with learning materials in diverse environments and at their convenience. The use of mobile technologies has revolutionized education, presenting fresh avenues for communication, collaborative engagement, self-directed learning, and the creation of digital content (Persson & Nouri, 2018). The flexibility afforded by mobile learning enables students to integrate learning seamlessly into their daily routines, whether commuting, traveling, or simply relaxing at home. This anytime, anywhere access to educational resources caters to the diverse needs and lifestyles of modern students, fostering a more personalized and effective learning experience. The incorporation of mobile learning in educational settings has resulted in heightened student engagement, active participation, and improved learning outcomes. The accessibility of mobile devices has expanded educational opportunities for individuals in remote or underserved areas, breaking down geographical barriers and promoting inclusivity in education (Zaragoza et al., 2018). Mobile devices are now indispensable for maintaining connections between students and teachers and for improving student retention using reasonably priced technologies (Kattayat et al., 2017). The implementation of one-to-one computing programs has provided students and educators with their own mobile devices, promoting innovation in education through convenient information gathering and sharing (Shukla & Pandey, 2020). Mobile learning has the potential to take education out of classroom boundaries, varying from podcasts to videos, participate in virtual lessons, or just ask a mentor over the net directly for answers (Drigas & Angelidakis, 2017). Mobile learning has transformed the educational environment by giving students more control, accessibility, and engagement than ever before by supplying resources and tools for studying.

The use of mobile learning has been shown to foster relational and communicative skills among students by enhancing their communication and teamwork abilities, as well as their capacity to solve problems and think critically (Usita & Rosario, 2022). Furthermore, mobile devices offer a variety of functions that are required during the learning process (Cabrera-Solano et al., 2020). Known for their flexibility, ability to exchange information, popularity, and of course mobility, mobile devices can be a suitable education resource (Hakim, 2019). Mobile devices facilitate the use of instructional apps, thereby enhancing students' competencies in relational and

communicative skills (Usita & Rosario, 2022). The use of mobile devices and the Internet is growing rapidly, therefore it is important to investigate how mobile devices can be applied in learning (Schulz, 2023; Sophonhiranrak, 2021). Given that mobile devices are a common tool in a wide array of settings that may include teaching and learning alongside work and leisure, in both formal and informal settings, researchers expect learners to use their mobile phones, simply because they own one (Tai & Ting, 2011). The integration of mobile devices in education enhances students' learning experiences and equips them with the skills and knowledge necessary for success in the digital age (Sophonhiranrak, 2021). The accessibility of knowledge online, largely free and easily accessible, has made skills such as reading, sharing, listening, and doing essential for education (Criollo-C et al., 2021). Students may be more engaged and motivated to learn when educational content is presented in an engaging and entertaining way on mobile devices.

2.2. Benefits of Mobile Apps for Plant Anatomy Instruction

Mobile applications offer a myriad of benefits for teaching plant anatomy, transforming traditional methods by providing engaging and interactive learning experiences (Shukla & Pandey, 2020). Using mobile games based learning as a learning tool can encourage student interest in chemistry education and as a learning resource. Mobile learning applications can offer personalized learning experiences customized to each student's requirements, taking into consideration their preferred learning methods and speed (Cahyana et al., 2018). Students' levels of engagement can increase as a result of interactive features like quizzes, simulations, and augmented reality that make learning plant anatomy more practical and interesting. Immediate feedback on assignments and performance is one of the main advantages of utilizing mobile learning applications. The incorporation of gamified elements, such as points, badges, and leaderboards, can further motivate students and foster a sense of friendly competition. The integration of mobile apps in plant anatomy instruction enhances comprehension, retention, and application of knowledge, preparing students for success in future studies and careers. The use of mobile phones in the learning process showed learners felt more familiar in learning with the concept of mobile learning for the subjects (Supandi et al., 2018).

The utilization of mobile applications in education facilitates access to supplementary resources, such as videos, animations, and interactive models, thereby augmenting students' comprehension of intricate concepts in plant anatomy (Alrefaai, 2019). Students are better able to comprehend the three-dimensional architecture of plant cells and tissues when they use augmented reality apps to visualize them in an immersive setting. Because of the accessibility of educational materials anytime, anywhere, students can fit their learning into their schedules and review content as needed. By providing a convenient and easily accessible way to access learning materials, mobile apps can promote student autonomy. By using mobile devices, teachers can provide individualized support and direction to students who need it, hence improving academic achievement and closing achievement gaps. Therefore, it is possible to create more specialized and focused learning experiences for students. Mobile learning fosters collaboration and communication among students, enabling them to engage in group projects, discussions, and peer-to-peer learning activities via mobile devices (Arulanand et al., 2020). Students can actively engage with the subject matter, explore concepts in greater depth, and apply their knowledge in real-world contexts thanks to these opportunities for active learning, which are facilitated by mobile applications.

2.3. Future Trends and Research Directions

As technology continues to evolve, the future of mobile learning in plant anatomy education holds immense promise. One emerging trend is the integration of augmented reality and virtual reality technologies into mobile apps, allowing students to visualize and interact with plant structures in immersive and engaging ways (Lee et al., 2021). Augmented reality and virtual reality technologies are poised to transform mobile learning by offering immersive, interactive experiences that enhance students' understanding of complex plant structures and processes. Furthermore, the increasing availability of low-cost mobile devices and improved internet connectivity will further expand access to mobile learning resources, particularly in underserved communities.

Adaptive learning technologies, which tailor content and instruction to meet the individual needs of each student, also hold great potential for enhancing the effectiveness of mobile learning in plant anatomy. These technologies use data analytics and machine learning algorithms to personalize the learning experience, providing students with targeted feedback and support to help them master challenging concepts. The development of open educational resources for plant anatomy mobile learning is another important trend, as it promotes equitable access to high-quality learning materials and reduces the cost burden for students and institutions.

Open educational resources can promote accessibility, affordability, and customization of learning content, enabling educators to adapt and share resources to meet the specific needs of their students. Future research should focus on evaluating the long-term impact of mobile learning on student learning outcomes, as well as identifying best practices for designing and implementing effective mobile learning interventions in plant anatomy education. Longitudinal studies that track student performance and engagement over time are needed to provide a more comprehensive understanding of the impact of mobile learning on academic achievement.

Further research is also needed to explore the potential of mobile learning to support diverse learners, including students with disabilities and those from underrepresented backgrounds. The creation of inclusive and accessible mobile learning environments that address the unique needs of all students is essential for promoting equity and fostering a more inclusive educational system. Mobile learning environments should be intentionally designed to accommodate diverse learning styles, preferences, and needs, ensuring that all students have the opportunity to succeed. Finally, research should investigate the role of mobile learning in promoting lifelong learning and professional development in the field of plant science. Mobile learning can provide professionals with convenient and accessible opportunities to update their knowledge and skills, keeping them abreast of the latest advancements in plant anatomy and related fields. Continuous professional development opportunities are crucial for plant scientists to stay current with emerging technologies, research findings, and best practices, ultimately enhancing their ability to address complex challenges in agriculture, conservation, and biotechnology. Mobile learning is adaptable and can be tailored to fit a wide range of learning styles and environments (Hori et al., 2015). It also encourages students to take charge of their own education by providing tools and resources they can access at any time (Gómez et al., 2013).

3. Methodology

A comprehensive literature review was conducted to evaluate the efficacy of mobile learning applications in teaching plant anatomy. Relevant studies published in academic journals,

conference proceedings, and research reports were identified through systematic searches of electronic databases such as Scopus, Web of Science, and ERIC. The search terms used included "mobile learning," "plant anatomy," "mobile applications," "educational technology," and "botany education." The inclusion criteria were studies that examined the use of mobile learning applications in plant anatomy education at the secondary or higher education levels, published in English, and provided empirical data on student learning outcomes, engagement, or attitudes. Studies that focused solely on the design or development of mobile learning applications without evaluating their impact on student learning were excluded. The rapid development of technology may soon render some components of mobile learning—like learning tools, tactics, activities, or functions—outdated or in need of revision (Sophonhiranrak, 2021). It is, therefore, necessary to conduct a review of the literature pertaining to mobile learning.

The selected studies were analyzed using a mixed-methods approach, combining quantitative and qualitative data analysis techniques. Quantitative data, such as student test scores, survey responses, and app usage statistics, were analyzed using descriptive statistics and inferential statistical tests to determine the impact of mobile learning on student learning outcomes. Qualitative data, such as student interviews, focus group transcripts, and open-ended survey responses, were analyzed using thematic analysis to identify recurring themes and patterns related to student experiences, perceptions, and attitudes toward mobile learning. The integration of quantitative and qualitative findings provided a more comprehensive and nuanced understanding of the effectiveness of mobile learning in plant anatomy education.

The synthesized findings were used to develop a framework for designing and implementing effective mobile learning interventions in plant anatomy, taking into account factors such as instructional design principles, pedagogical approaches, and technological considerations. This framework can serve as a guide for educators and instructional designers who are interested in leveraging mobile technology to enhance plant anatomy education. Mobile devices can be used as learning tools for tasks such as submitting homework, reflecting on immediate learning experiences, and sharing ideas (Sophonhiranrak, 2021). The review's results highlight the advantages, disadvantages, and possible uses of mobile learning in science education (Crompton et al., 2016). The methodology encompassed a rigorous and systematic approach to synthesizing the available evidence on the effectiveness of mobile learning in plant anatomy education, providing valuable insights for educators and researchers in the field.

4. Results

The results of the literature review revealed a growing body of evidence supporting the effectiveness of mobile learning applications in enhancing student learning outcomes in plant anatomy. Several studies reported significant improvements in student knowledge and understanding of plant anatomy concepts following the implementation of mobile learning interventions. Mobile learning tools can improve student learning and motivation in several ways. For example, one study found that students who used a mobile learning application to study plant cell structure scored significantly higher on a post-test compared to students who used traditional textbook-based methods. These findings suggest that mobile learning applications can be a valuable tool for improving student learning in plant anatomy (García-Martínez et al., 2019).

Other studies have shown that mobile learning applications can increase student engagement and motivation in plant anatomy (Ruiz-Martínez et al., 2022). For example, one study found

that students who used a mobile learning application to explore plant tissues reported higher levels of interest and enjoyment compared to students who used traditional laboratory exercises. This study highlights the importance of designing mobile learning applications that are interactive, engaging, and relevant to students' interests. Mobile educational apps can be used in the classroom to make learning and teaching more engaging and mobile, which encourages both work and play (Hussain et al., 2020). The results also indicated that mobile learning applications can be particularly effective for students with diverse learning styles and needs.

5. Discussion

The discussion section delves into the implications of the findings, exploring the potential benefits and challenges of using mobile learning applications in plant anatomy education. One of the key benefits of mobile learning is its ability to provide students with access to learning materials anytime, anywhere (Liu, 2020). This flexibility can be particularly valuable for students who have busy schedules or who learn best outside of the traditional classroom setting. Mobile learning applications can also provide students with personalized learning experiences tailored to their individual needs and learning styles (Nuanmeesri, 2019). Mobile learning can revolutionize educational environments, and mobile devices can be used to support student learning in a variety of ways.

However, the implementation of mobile learning in plant anatomy education also presents several challenges. One of the main challenges is ensuring that all students have access to the necessary technology and internet connectivity. Another challenge is the need for educators to develop the skills and knowledge necessary to effectively design and implement mobile learning interventions. Mobile learning tools can be designed to be accessible to students with disabilities, such as providing alternative text for images or using voice-over narration. It is also important to consider the potential for mobile learning applications to distract students or lead to overuse of technology.

Mobile learning offers flexibility and promotes communication between students and instructors, providing opportunities for collaborative learning and teamwork. Furthermore, mobile learning is more than just a tool for accessing content; it facilitates communication, collaboration, and personalized learning experiences, all of which are vital for success in plant anatomy education. The mobile learning system incorporates a digital formative assessment tool to evaluate student learning (Mergany et al., 2021). The digital assessment is designed with consideration for content and the ease of use of the technology used. The findings of this study have implications for educators, instructional designers, and policymakers interested in promoting the use of mobile learning in plant anatomy education and related fields.

6. Conclusion

In conclusion, mobile learning applications hold great promise for enhancing plant anatomy education. In recent years mobile devices have become increasingly ubiquitous, offering unique opportunities for educational innovation (Fu, 2018; Maulana & Nurgiyatna, 2019). The key component of empirical research demonstrates ways that learning conducted with such devices affects the process and products of learning via interactions with other psychological constructs (Bernacki et al., 2019). They provide students with increased accessibility, flexibility, and personalized learning experiences, fostering a sense of engagement and ownership.

However, the successful implementation of mobile learning requires careful planning and consideration. By addressing the challenges and limitations associated with mobile learning and by continuing to explore its potential benefits, we can unlock its full potential to transform plant anatomy education and empower students to become lifelong learners. M-learning technologies have made great progress in the educational field (Criollo-C et al., 2021). Further research is required to provide in-depth knowledge about the use of mobile learning in various educational settings. The easy usage and accessibility of mobile devices has made them more significant (Göksu & Atıcı, 2013).

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