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Integrating Mobile Applications to Enhance the Practice of Plane Surveying

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This paper explores the use of mobile applications in surveying education to enhance student engagement and learning outcomes. A mobile app was developed and integrated into a Construction Surveying course to address limitations of traditional teaching methods, particularly in practical skill acquisition. The study highlights how mobile apps provide an interactive, hands-on approach that enhances students' understanding of surveying concepts and practical skills. By incorporating visualization tools, the mobile app offers students the opportunity to engage in learning experiences. To assess the impact of mobile app integration on student learning, a pre- and post-survey analysis was conducted. The analysis aimed to evaluate improvements in students' comprehension, engagement, and practical skills after using the mobile app. Results revealed a 25% improvement in measurement accuracy, a 30% increase in error-correction abilities, and a 20% enhancement in data visualization skills. Furthermore, students showed a higher retention of key surveying principles, with an improvement in applying theoretical knowledge to their field exercises. Qualitative feedback indicated heightened engagement, improved comprehension of theoretical concepts, and increased confidence in field tasks. The paper concludes by highlighting the potential of mobile apps to bridge the gap between theory and practice in surveying education and suggests areas for further research.

Keywords: Plane Surveying, Mobile App in Surveying, Surveying Education

Introduction

The practice of surveying a terrain, or plane, requires extensive practice with surveying instruments within the framework of a complex plane setting. These ideas are explored in greater detail in the Elementary Surveying Course section. In addition, the demand for new surveyors in the industry is increasing, while knowledge transfer opportunities continue to decline. The construction industry is one of the largest sectors in the United States economy, with 6.4 percent of GDP spent on construction projects annually (U.S. BEA, 2021). Consequently, surveyors' employment is anticipated to grow by 2% in the next decade (U.S. BLS, 2021). Surveying job opportunities will continue to expand, driven by tasks such as conducting surveys on land sites and property boundary lines, examining previous records and ensuring data accuracy, measuring land features, building maps, reporting on survey results, providing data for legal purposes, and collaborating with engineers and architects on diverse types of projects. To address these demands, the construction sector must innovate its training and recruitment strategies to effectively prepare the next generation of surveyors.

The Construction Surveying course, as a fundamental course in undergraduate Construction Management and Civil Engineering curricula, often faces challenges in bridging theory and practice. This study focuses on developing a mobile app to enhance learning outcomes by providing an interactive tool. The development objectives of this study were to (1) develop a mobile app to provide a learning environment for users; (2) better understand how a mobile app can enhance learning surveying outcomes compared to traditional methods; and (3) provide a set of learning experiences to train students, educators, and construction workers. In this paper, we highlight the limitations of traditional teaching methods in conveying essential surveying concepts and outline the course structure and learning objectives, emphasizing the technical skills students are expected to master. Then, we examine the integration of mobile app techniques, evaluating their potential to improve students' understanding and engagement. Figure 1 provides an overview of the study's development approach.

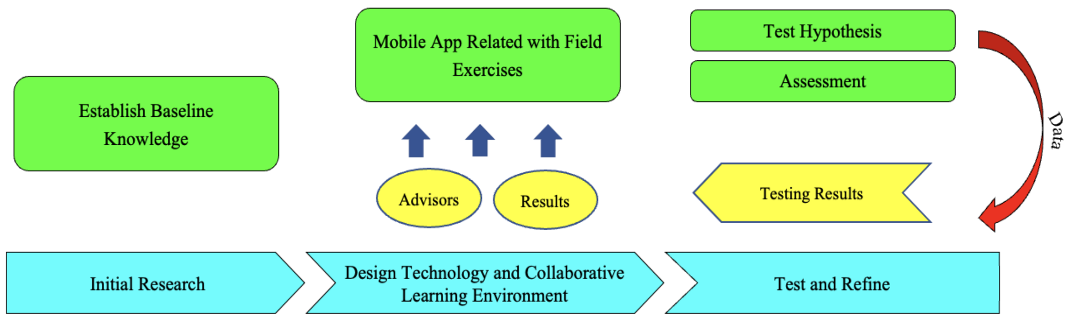

Figure 1. Overview of the study's approach

Background and Surveying Course Overview

The Elementary Surveying course is taught in programs such as Construction Management or Civil Engineering programs. Students are introduced to basic concepts and practical techniques in surveying practices. This course covers surveying operations and computations, theory of errors in observations, fundamental concepts of horizontal, vertical, and angular measurement, traverse computations, horizontal and vertical curves computations, utilizing tapes, automatic levels, and total stations. To provide an up-to-date presentation of surveying equipment and procedures, automatic levels are stressed as an instrument for elevation determination. Widely used in surveying and construction projects, automatic levels measure height differences within the same horizontal plane in a process known as leveling (Ghilani et al., 2021). Automatic levels are used in conjunction with a known set of objects or benchmarks. Similarly, total stations are instruments for making angle and distance determinations. Total stations measure horizontal, vertical, and slope distances and horizontal and vertical angles from the instrument to a particular object or point.

In this course, students are introduced to the principles and practices of surveying, including measurements, subsequent computations, and analyses of collected data. Accurate data collection, adequate measurements, and data collection from the field require a combination of surveyor skills and surveying equipment applied with the surveyor's judgment. Understanding the logic and sequence of field activities is key to being able to identify various errors and factors that may affect the delivery of a surveying task. However, without prior experience, these concepts are often difficult to grasp through traditional teaching methods alone. Hands-on interaction is crucial for mastering these skills. For example, students learn about the theory of leveling and the procedures in determining elevations of points based on a known point or benchmark. This approach reinforces theoretical knowledge and helps students develop the problem-solving skills needed to surveying challenges.

In the traditional instructional model, the instructor provides an example context and demonstration of leveling during the lecture. Students engage in a few structured class activities, homework assignments, and quizzes on the same topic to reinforce their understanding of leveling concepts, procedures, and computations. Students also learn how to work with leveling rods and automatic levels in controlled settings such as indoors or on the campus grounds. Further, they learn to work as a team to generate a plan for a given field and coordinate their responsibilities in the field to obtain usable data for their analysis and final report. At this point, students should be familiar and feel comfortable with the field procedures, working with an automatic level, and knowing how to read leveling rods. They should also be able to notice, and accommodate for, any potential human, environmental, and instrumental errors.

However, despite well-designed traditional teaching methods, these tasks are usually difficult for students with no prior experience. During the field exercise, practice is often different from theory, and about seventy percent of students must repeat their fieldwork. They feel frustrated doing the work again and recollect the required data from the field. Students often make errors, including setting up automatic level incorrectly, not holding the level rod vertically, moving the level rod or level instead of being rotated for foresight reading, and settlement of tripod or rod on mud, selecting the route and the spot for their level rod and tripod, keeping the distance of rod for the backsight and foresight reading is almost equal, and recording errors. Eliminating some of these errors needs the intuition that comes with practice and repetition that is part of the learning experience. Instructors can catch and provide feedback to correct some of these errors. Experienced peers can also assist others. It is important to note that fieldwork is time-consuming, depends on good weather, and is constrained by limited equipment, travel funds, and access to various locations (U.S. BLS, 2021). A notable challenge in the collaborative workflow is coordinating student roles during field exercises. The leveling field exercise is done with three students working together, having three different roles including instrument operator, note keeper, and rod person. If any of the participants make an error, it will impact the whole team and cause a misclosure error in the result. For example, if the instrument person does not set up the instrument correctly, the reading will be inaccurate. Similarly, if the rod person does not keep the rod vertical at the time of reading, the measurement will not be accurate.

Traditional surveying education faces significant challenges, including data accuracy, error identification, and a deep understanding of field techniques. There is often a disconnect between theoretical knowledge and practical applications among students with limited field experience. Additionally, traditional methods lack the interactivity needed to engage students, particularly those accustomed to digital platforms and dynamic learning environments. Another significant challenge is the difficulty in understanding error sources and mastering error-correction techniques, which can be abstract and hard to comprehend through lectures alone. These limitations highlight the need for innovative teaching methods that provide hands-on learning experiences and interactive feedback, making mobile apps an ideal tool to address these gaps.

The Use of Mobile Applications in STEM Education

The integration of mobile applications into STEM (Science, Technology, Engineering, and Mathematics) education has gained significant momentum in recent years, driven by the ubiquitous adoption of mobile devices and the growing demand for engaging and accessible educational tools (Johnson et al., 2013). The adaptability, interactivity, and engagement capabilities of mobile apps make them an ideal addition to traditional teaching methods, especially in STEM fields (Zhu and Wang, 2023). Nonetheless, challenges remain regarding access, implementation, and efficacy across diverse student populations in relation to mobile applications' ability to enhance understanding, motivation, and engagement in STEM subjects (Shurygin et al., 2024). The following provides an overview of the impact of mobile applications and the challenges in STEM learning experiences.

Enhancing student engagement and motivation: Several studies highlight that mobile applications can significantly enhance student engagement and motivation in STEM education (Bano et al., 2018; Bray and Tangney, 2016; Shchedrina et al. 2020; Zydney and Warner, 2016). Mobile apps frequently integrate gamification, interactive simulations, and real-time feedback, making learning more engaging and immersive for students (Lampropouloset al. 2022). A study by Wang et al. (2021) demonstrated that gamified STEM applications not only boosted engagement levels but also improved the retention of complex scientific concepts among middle school students. Similarly, other studies observed that mobile apps with interactive experiments encouraged students to explore scientific principles outside of the classroom, fostering a continuous learning mindset (Hirsh-Pasek et al., 2015).

Supporting conceptual understanding: In STEM education, conceptual understanding is essential for building foundational knowledge. Mobile applications provide simulations, visualizations, and interactive problem-solving exercises that enable students to better grasp abstract or complex concepts (Park, 2011). For instance, a study demonstrated that engineering students using physics simulation apps achieved a higher understanding of mechanics concepts than those using traditional textbooks (Purba et al. 2019). The interactive nature of these applications allows students to manipulate variables and observe outcomes in real-time, which enhances their ability to understand and retain difficult concepts. Similarly, digital tools have been shown to be particularly effective in mathematics education, where apps that visualize equations and functions have notably improved student comprehension (Dahlan et al., 2022).

Personalized and adaptive learning: One of the most promising aspects of mobile applications in STEM education is their ability to provide personalized learning experiences. Adaptive learning algorithms embedded in many STEM applications analyze students' responses and adjust content difficulty, accordingly, allowing for differentiated instruction that meets individual learning needs (Songer et al., 2020). For example, adaptive math applications showed that personalized pathways led to significant improvement in mathematical problem-solving skills for students in elementary schools (Bang et al., 2023). This approach to personalized learning is particularly transformative in STEM fields, where students often advance at varying rates depending on their familiarity with foundational concepts (Chen, 2008; Pardo et al., 2018).

Bridging access gaps in STEM education: Mobile applications can also play a critical role in bridging access gaps, promoting greater equity in STEM education (Mouza and Barrett-Greenly, 2015). In many regions, mobile devices are more accessible than computers, and STEM apps can thus offer an affordable alternative to traditional resources like laboratory equipment or expensive software (Pearce and Rice, 2013). Studies have shown that mobile-based STEM learning is particularly effective for students in under-resourced schools, where the high costs of lab materials or advanced computers might otherwise restrict their opportunities for hands-on STEM education (Abildinova, 2024; Lubis et al., 2023).

Challenges in mobile STEM education: Despite their benefits, mobile applications in STEM education face several challenges. Technical limitations, such as device compatibility, limited bandwidth, and unreliable network access, can hinder the effective use of STEM apps (Criollo-C, 2021). A study by Beach and O'Brien (2014) found that students may find it difficult to connect app-based simulations with real-world phenomena without proper guidance. In addition, there are differences in effectiveness between STEM disciplines and educational levels when it comes to mobile apps (Abolfazli et al. 2014). While apps are highly effective in foundational science and math education, their utility diminishes in more advanced engineering or scientific fields, where concepts and tasks are often more complex.

Integration of Mobile Apps in Construction Surveying Education

There is a growing need for innovative teaching methodologies that foster the competencies needed to better prepare students for future job opportunities. Kolb's experiential learning model (Kolb and Kolb, 2005) provides a framework for helping interaction and learning during classroom laboratory sessions. Within this model, students meet a new experience, reflect on the experience, learn from experience variants (mistakes and improvements), plan and apply learned concepts and are allowed to repeat the experience (Figure 2). By replicating these experiences within a mobile app, students can engage in the same learning cycle without the limitations of physical space or logistical challenges. By combining the experiential learning cycle to the collaborative learning environment, learners can expand upon the abstract conceptualization stage through discussion and ideation opportunities. Moreover, empowering students with control over their learning enhances their sense of self-efficacy, creating a safe and efficient environment that promotes deeper engagement.

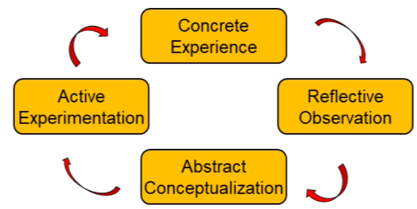

Figure 2. Kolb's experiential learning theory

Methods

The study employed a mixed-methods research paradigm, combining qualitative and quantitative approaches to evaluate the impact of mobile applications on student learning in a Construction Surveying course. A sample group of nine undergraduate students enrolled in the course was selected based on their course enrollment. Participants had varying levels of prior experience with surveying concepts and tools, and no formal prerequisite knowledge was required. The study was conducted over three weeks and included three phases. In the pre-test phase, a survey assessed students' baseline knowledge and skills in leveling tasks, error identification, and data visualization. During this phase, students received lecture-based instruction on leveling concepts without using the mobile application. In the intervention phase, the mobile application was introduced following the lecture and before laboratory sessions. The app included two modules: Leveling I, which focused on the fundamentals of leveling (Figure 3), and Leveling II, which provided step-by-step guidance for laboratory exercises (Figure 4). Students completed interactive activities, such as simulations and error-correction exercises, and participated in a class activity requiring them to fill out a data collection table (Figure 5).

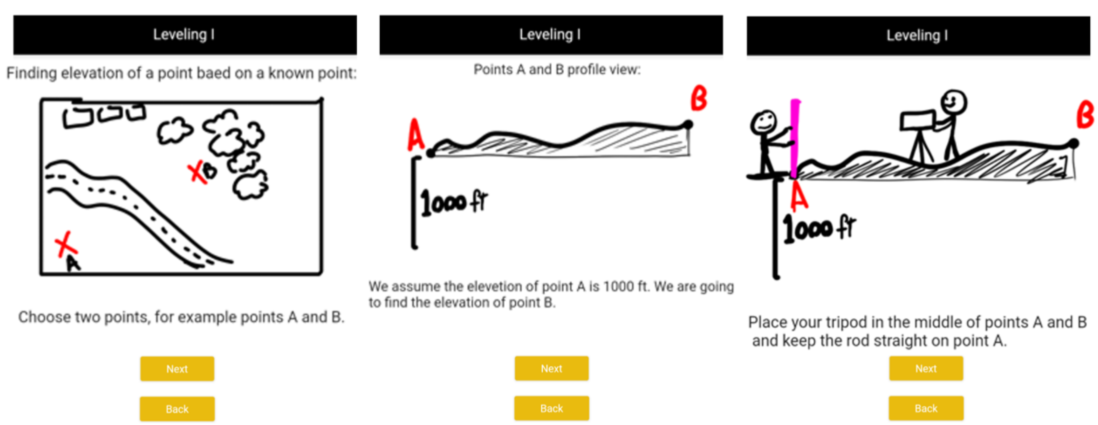

Figure 3. Screenshot of the mobile app interface for Leveling I, Fundamentals of Leveling

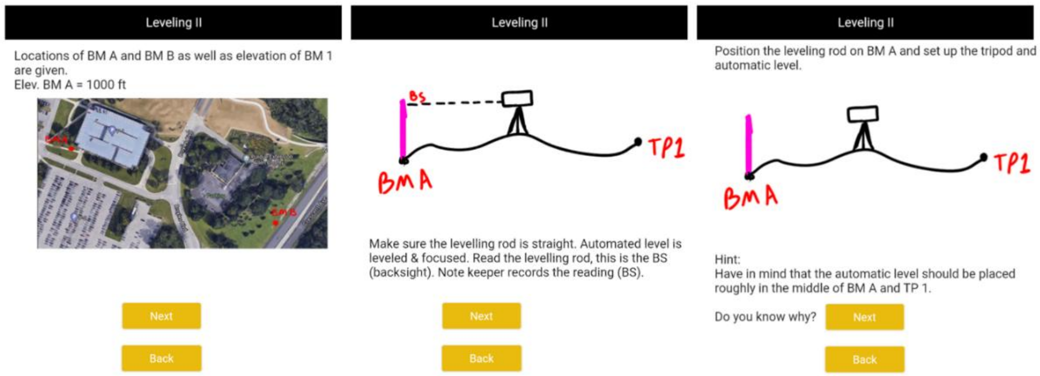

Figure 4. Screenshot of the Mobile App Interface for Leveling II, Providing Step-by-step Guidance for Completing the Lab Exercises

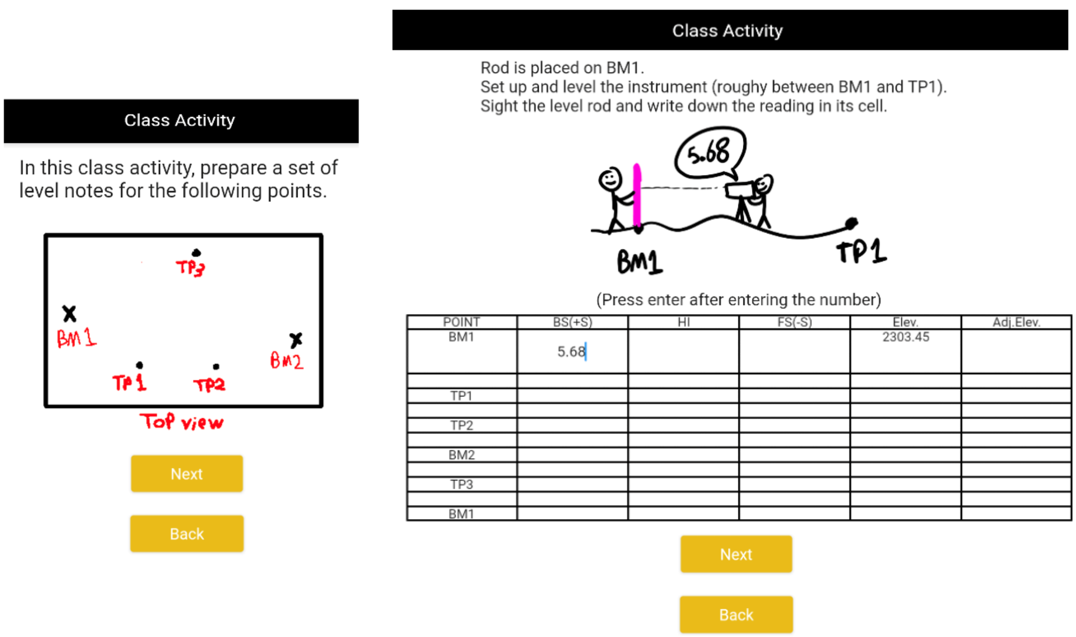

Figure 5. Screenshot of the Mobile App Interface for Class Activity

The app's design ensured error-checking by preventing progression without correct data entries, thereby reinforcing data validation skills. These figures illustrate the app's key components and how it guided students through the learning process. In the post-test phase, a survey was administered after the laboratory sessions to evaluate changes in comprehension, engagement, and confidence. Students also used the mobile app to finalize their fieldwork data and perform error-checking tasks. Figures 3 to 5 showcase how the app supported students in organizing and verifying their data during this phase. The app's structured approach allowed students to identify and correct errors on their own, enhancing their understanding of the surveying process.

Quantitative data from the pre- and post-surveys were analyzed to measure improvements in measurement accuracy, error-correction abilities, and data visualization skills. Likert-scale questions provided numerical data for statistical analysis, while open-ended survey questions offered qualitative insights into students' experiences. The conclusion that 85% of students reported increased confidence was based on a post-survey question asking, “How confident do you feel in performing surveying tasks after using the mobile app?” Responses categorized as “increased confidence” included those selecting “Agree” or “Strongly Agree” on a 5-point scale. Qualitative feedback was thematically analyzed to further explore student engagement and perceptions.

Analysis of Results and Student Feedback: Quantitative and Qualitative Results

A post-survey was administered to measure changes in comprehension, engagement, and confidence. This section presents an analysis of the results and feedback collected from a surveying course involving nine students. Both quantitative data and qualitative responses were gathered to evaluate the effectiveness of the developed mobile app.

Evaluation of Pre- and Post-App Use

The study employed two primary data collection methods, pre- and post-survey assessments. Students completed surveys to share feedback on their experiences using the mobile app. These surveys provided meaningful perspectives into perceived improvements in understanding, engagement, and confidence while performing surveying tasks.

Quantitative Results of the Pre- and Post-App Use Evaluation

The pre- and post-survey assessments revealed statistically significant improvements in student performance across three key areas. In terms of accuracy in measurement tasks, students improved by 25%, with the mean pre-test score increasing from 3.1 to 3.9 ($p < 0.05$). Before using the app, many students struggled with precise elevation measurements, but the app’s interactive guidance enhanced their precision. Regarding error identification and correction, students showed a 30% improvement, with mean scores rising from 2.8 to 3.6 ($p < 0.01$). The mobile app provided immediate feedback during simulations, enabling students to refine their techniques and improve accuracy. For data visualization and analysis skills, test scores improved by 20%, with the mean pre-test score increasing from 3.2 to 3.8 ($p < 0.05$). The app’s graphical representations helped students better comprehend and analyze data relationships.

Qualitative Evaluation of Student Experiences

Qualitative data from student surveys highlighted several positive impacts of the mobile app on learning. Over 90% of students noted that the app made learning more interactive and enjoyable compared to traditional methods. Students appreciated the gamified elements and step-by-step guidance, which helped them maintain focus and interest in the material. They also expressed that the app effectively bridged theoretical knowledge and practical application. Visualizing tasks such as elevation measurements and error identification within a digital environment improved their understanding of abstract concepts. Additionally, 85% of students reported increased confidence in performing laboratory exercises after using the app. The app’s supportive environment allowed students to practice procedures, make mistakes, and learn from them before engaging in hands-on fieldwork. Students also mentioned that the app helped them retain information better and apply it more effectively. Table 1 summarizes the quantitative results from the survey assessments, highlighting improvements in measurement accuracy, error-correction abilities, and data visualization skills.

Table 1. Quantitative Results of Pre- and Post-Survey Assessments

Metric	Pre-Test Mean	Post-Test Mean	Improvement (%)	p-value
Measurement Accuracy	3.1	3.9	25%	<0.05
Error Identification/Correction	2.8	3.6	30%	<0.01
Data Visualization Skills	3.2	3.8	20%	<0.05

The pre- and post-survey data demonstrate that mobile app integration positively impacts student learning in Construction Surveying course. The improvements in all measured areas including measurement accuracy, error identification, and data visualization skills indicate that the mobile app successfully enhanced students' practical surveying abilities. The 25% improvement in measurement accuracy shows that students were better able to take and record precise measurements after using the app, a key skill for their fieldwork. The 30% increase in error identification and correction skills suggests that the app helped students become more adept at recognizing and addressing mistakes in their work. Additionally, the 20% improvement in data visualization skills reflects the app's effectiveness in helping students better understand and interpret surveying data, such as elevation measurements and spatial relationships. The statistical significance of these improvements, as indicated by the low p-values (<0.05 and <0.01), confirms that the mobile app had a meaningful impact on student learning outcomes. The app provided an active learning environment where students could visualize concepts and apply theoretical knowledge to practical situations.

Conclusions

The integration of mobile app techniques in surveying courses offers a promising approach to modernizing traditional instruction. Mobile apps enhance students' understanding of complex surveying concepts and practical skills through interactive, experiential learning. The teaching method is not only aligned with the technological preferences of current students, but it also mirrors the advancing digital tools that are used in the industry. According to the study, mobile apps can improve student comprehension and engagement in surveying education. Students can practice essential skills in a virtual environment before applying them in a field environment by using mobile apps for courses involving laboratory or fieldwork. Key benefits of this integration include increased student engagement through hands-on learning and improved practical skills in data collection and analysis. Moreover, real-time feedback enables students to recognize errors and develop strategies for correction, enhancing their problem-solving capabilities. These advantages demonstrate the effectiveness of mobile app integration in making surveying education more accessible, practical, and relevant to contemporary educational needs. As technology continues to evolve, these tools are poised to play an increasingly crucial role in preparing students for the demands of the construction and engineering industries.

Mobile apps have the potential to enhance surveying education by integrating gamification and user-centered design, making learning more accessible, engaging, and interactive. By utilizing proven engagement strategies, these apps can bridge the gap between theory and practice, helping students build confidence and skills while expanding access to technical knowledge for diverse learners. As part of a broader trend that includes technologies like virtual reality and artificial intelligence, mobile applications offer immersive, hands-on experiences that were once confined to physical spaces. This approach not only supports technical skill development but also broadens access to high-quality education, preparing students to excel in a rapidly evolving field.

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