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ENHANCING ENGAGEMENT IN INDUSTRIAL DESIGN EDUCATION WITH MAR-SLS: A QUASI-EXPERIMENTAL STUDY USING MOBILE AR

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Abstract:

The application of mobile Augmented Reality (MAR) has become a growing phenomenon, making this technology more accessible and integrated into the learning process, offering new opportunities to enhance learning experiences. This study explores the effectiveness of a custom-developed mobile AR Sketch Learning System (MAR-SLS), which is designed to support industrial design students in visualizing 3D product models, particularly during sketching and rendering tasks. A quasi-experimental design was employed to evaluate the intervention. Student engagement and motivation were assessed using the Instructional Materials Motivation Survey (IMMS), while performance was assessed by two senior lecturers from industrial design department. Independent samples t-tests was conducted to compare test scores between two groups. Results revealed that students using MAR-SLS scored significantly higher ($p<0.05$) across all IMMS dimensions (attention, relevance, confidence, and satisfaction), performance, and engagement compared to those in the control group. These findings suggest that MAR technology, as implemented through MAR-SLS, can effectively enhance student engagement and motivation. Educators should consider pedagogical strategies when integrating such technologies into the curriculum to maximize learning outcomes.

Keywords:

Mobile Augmented Reality (MAR), Student Engagement, Motivation, Industrial Design Education, Instructional Materials Motivation Survey (IMMS)

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Introduction

As the world become more digitalized and technologically advanced, traditional modes of teaching in higher education, particularly in design education, has been disrupted (Rapanta et al., 2021). Students, including industrial design students, are now challenged to keep pace with rapid technological advancements and are expected to develop skills that extend beyond conventional academic knowledge (Meyer & Norman, 2020).

Industrial design education plays a vital role in equipping students with the skills and knowledge needed to design functional and visually appealing products. Among these skills, product sketching and rendering are foundational, enabling students to visualize and communicate their design concepts during the development process. To master product sketching and rendering skills, students need to show correct proportions, realistic textures, and detailed material representation. Traditionally, these concepts are taught using two-dimensional (2D) visual aids such as printed sketches and PowerPoint slides (Kolko, 2008). However, these static media often fall short in conveying the depth, realism, and interactivity needed to fully support students' conceptual understanding and creative exploration (Kim et al., 2023). This reveals a critical problem in contemporary industrial design education that conventional teaching methods based on 2D content are increasingly inadequate for addressing the demands of modern industrial design education. As a result, these traditional methods may hinder student creativity and engagement, and fail to provide the immersive, realistic experiences needed for effective learning in design-related tasks (Karadoğaner, 2020).

Mobile Augmented Reality (MAR) has emerged as a promising solution to bridge this gap. By overlaying digital content onto the physical environment, MAR offers dynamic, interactive, and immersive tools that can enhance students' understanding and engagement with design concepts (Karadoğaner, 2020). Recent studies have further shown that MAR can support student learning by making abstract or complex topics more accessible, especially through marker-based systems that bring 3D models into real space (Bermejo et al., 2023; Criollo-C et al., 2021; Joshi et al., 2020). Furthermore, researchers have explored the potential of MAR to enhance student learning, engagement, and motivation, which are recognized as key factors in successful teaching and learning (Al-Azawi, 2018; Kahu, 2013; Rane et al., 2023; Wei et al., 2015). By creating highly interactive learning environments, MAR can transform passive learning into active exploration, supporting both cognitive development and practical skills acquisition (Al-Azawi, 2018; D'Angelo, 2018; Rane et al., 2023).

Despite its benefits, a gap remains in understanding the specific impact of MAR on performance, engagement, and motivation within industrial design education, particularly in the context of sketching and rendering tasks. Addressing this gap is crucial for guiding higher education institutions in adopting technology-enhanced teaching approaches that align with contemporary program standards and industry expectations.

Research Objectives and Questions

This study aims to investigate the effect of MAR-based learning on student engagement, motivation, and performance within the context of industrial design education, with a particular focus on sketching and rendering tasks. The specific objective is to evaluate the effectiveness of the MAR-SLS system as a learning tool. Specifically, it addresses the following research questions:

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RQ1: How does MAR influence student performance in industrial design education, specifically in sketching and rendering tasks?
RQ2: How does MAR influence student engagement in industrial design education, specifically in sketching and rendering tasks?
RQ3: How does MAR influence student motivation in industrial design education, specifically in sketching and rendering tasks?

Literature Review

Industrial design education curriculum focusses on visual design and technical knowledge in order to inspire students for actual industry difficulties. The rise of MAR offers an innovative solution to overcome the limitations of traditional methods (Nurhidayati & Azhar, 2023). The educational landscape is being radically transformed by increasing investments in AR technologies (Abdullah, 2021). With AR tools, it enables students to visualize complex concepts like view angles, spatial relationships, and depth perception more intuitively (Tavares & Cortiz, 2021).

The Potential of AR in Design Education

AR offers significant potential in enhancing design education by enabling the visualization and interaction with three-dimensional (3D) objects within real-world environments. This technology allows design students to view and interact with actual surroundings or environments. By exploring different angles of objects perspectives, they can rotate and enlarge the objects via AR applications. Wu and Cheng (2022) highlight how AR enables even novice users to generate 3D models intuitively by drawing strokes around physical objects and referencing captured point data, leading to greater precision and control in modelling tasks. This innovation empowers students to examine complex forms and structures from various angles, enhancing both comprehension and confidence in the design process.

Furthermore, AR technology serves as a valuable learning aid to enrich students' design understanding towards practical of space such as size, scales or ratios and depth of axis. According to Trice and Hokanson (2019), incorporating AR into drawing sessions can enhance students’ ability to translate three-dimensional forms into accurate two-dimensional representations. With AR, students can engage in sketching and rendering activities with increased assurance and precision. Research also suggests that AR positively influences students' learning experiences by improving motivation, visualization skills, and engagement. Faria and Miranda (2023) found that AR allows students to engage more deeply with content by making intangible ideas tangible and interactive. As such, AR is emerging as a transformative tool in design education, bridging the gap between theoretical knowledge and hands-on practice.

AR in Industrial Design Education

In the context of industrial design, AR can elevate the quality of design presentations by superimposing digital content onto physical media. This not only enhances user experience but also make it easier for students and educators to communicate product specifications effectively (Topal & Şener, 2015).

AR applications allow industrial design students to interact with 3D models from multiple angles by adjusting camera positions and perspectives. This interactive capability fosters spatial awareness and improves comprehension of form and function. Ding et al. (2024)

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highlight that AR tools enable real-time sketching on 3D models with customizable precision and editable anchor points, significantly enhancing both productivity and adaptability across projects of varying scale and complexity.

Moreover, AR applications can support accurate drawing by overlaying perspective grids and alignment guides directly onto the drawing plane. This not only improves precision but also reinforces visual thinking and perspective-based drawing skills. Abdullah (2023) emphasized the effectiveness of AR-based courses in helping both students and lecturers create immersive learning experiences that blend traditional sketching with the precision of digital tools. The immediate feedback enabled by AR technologies allows students to identify and correct errors quickly, accelerating skill development. While the overall impact of AR on learning effectiveness may be modest, research by Garzón et al. (2019) identified that the most frequently reported benefits were improvements in knowledge acquisition and student motivation. These outcomes reinforce the value of AR as a complementary tool in industrial design education, especially when integrated thoughtfully into the curriculum to support both conceptual understanding and hands-on practice.

Student Motivation and Engagement

Student motivation and engagement play as main role in progress learning to persist through challenges and strive toward their academic goals. When learning is presented in enjoyable and stimulating ways, students are more likely to explore topics deeply and maintain interest which is benefiting both learners and educators (Filgona et al., 2020). Alternatively, learners who are less motivated or unmotivated may find it difficult to learn effectively, leading to frustration, disengagement, and diminished interest in the subject matters (Amerstorfer & Von Münster-Kistner, 2021). As a result, identifying these obstacles is important to ensure all students benefit from the emerging technology such as AR.

Student engagement has been widely recognized as another important factor in academic success. Active participation in the learning process promotes both motivation and achievement, ultimately enhance classroom performance (Lee et al., 2019). The convincing interchange between motivation and engagement significantly influences the achievement of Program Learning Outcomes (PLOs). Technologies like AR can support this process by fostering visual and interactive learning, particularly in disciplines like design education, where spatial reasoning and visual accuracy are key. AR applications allow students to manipulate 3D models, solve complex visual challenges, and engage with content in innovative ways while increasing their motivation and enthusiasm for learning.

Recent studies provide growing evidence of AR's effectiveness in enhancing student engagement and motivation. Huey et al. (2024) reported that students using a mobile AR (MAR) application experienced high levels of satisfaction and accomplishment, highlighting the potential of MAR as an effective learning tool. Similarly, Carrera et al. (2018) found that AR on tablets served as a motivating platform for developing 3D visualization skills and enhancing students' spatial comprehension. Cabero et al. (2019) also demonstrated that the integration of AR-based notes on mobile devices significantly improved student engagement and academic success. These findings underscore the transformative potential of AR in higher education, particularly in design-related fields. By combining interactivity, visual immersion, and real-time feedback, AR can effectively address motivational barriers and foster sustained student engagement.

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Methodology

Participants

A quasi-experimental design was conducted in a product sketching course at a college. 48 diploma students, aged 18-20 years old, major in industrial design were recruited in this study. These students were then divided into two groups, group A and group B, randomly and each group consisted of 24 students.

In this study, participants from group A were assigned as control group whereas participants from group B were assigned as experimental group. In control group, the participants were taught the sketching concepts by the lecturer using traditional multimedia courseware which is the Power point slides with the support of video and demonstration. In experimental group, the participants were taught using the custom-developed Mobile AR Sketch Learning System (MAR-SLS) to demonstrate the same sketching concepts by the same lecturer and they were able to self-practice with the system.

Mobile AR Sketch Learning System (MAR-SLS)

The MAR-SLS system includes three core features designed to enhance students' understanding of product sketching concepts. First, it provides interactive 3D models of products that users can rotate and scale from multiple perspectives, allowing for dynamic visualization. Second, it features a screenshot and download function that enables learners to capture their preferred viewpoint and proportions with a single click for reference in their sketches. Third, the system offers toggle buttons to display the 3D model on either landscape or portrait paper layouts, simulating the sketching environment on actual drawing sheets (see Figure 1). These features are designed to empower students to manipulate learning materials from their preferred perspectives, with the aim of enhancing spatial understanding and supporting more accurate and confident sketching.

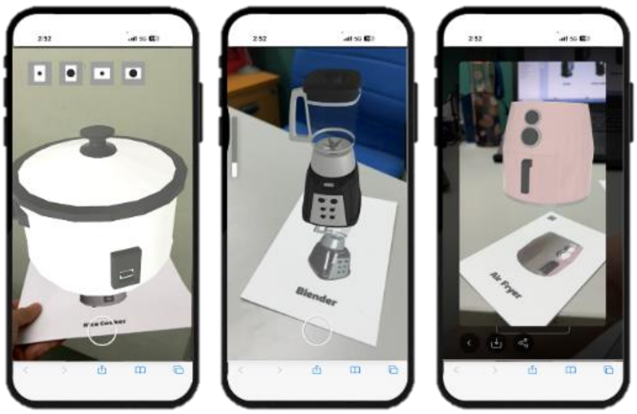

Figure 1: Three Key Features in the MAR-SLS System: (1) Buttons That Enable Users to Display Product Proportions in Both Landscape and Portrait Formats; (2) The Ability to Adjust the Scale of the 3D Model for Flexible Viewing; And (3) A Screenshot and Download Function for Effortlessly Capturing and Saving Desired Views

Procedure

The experiment was conducted within a single session of a product sketching course, with a total duration of three hours. The session began with a 10-minute introductory briefing delivered by the researcher, outlining the objectives of the study and the tasks to be completed.

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All participants from both groups were then assigned a pre-test to assess their baseline knowledge of sketching concepts. The pre-test includes tasks related to sketching that measure comprehension and practical application. After completing the pre-test, the learning session started immediately. The entire learning session spanned 60 min. Both the experimental and control groups received the same learning materials for product sketching, but the delivery methods differed. The experimental group used the Mobile AR Sketch Learning System (MAR-SLS), while the control group used traditional multimedia courseware. The comparison between experimental AR-based and traditional teaching methods are further described in detail in Table 1.

Table 1: Description and Comparison Between Experimental Teaching Approach and Traditional Teaching Approach

Traditional Teaching Approach Topic for plastic product rendering	Experimental Teaching Approach
Lecturer: explains the way to render plastic product (e.g. Toaster) using Power Point slide with video and demonstrates how to render the product in the classroom. Assign exercise	**Lecturer:** Teaching topic is the same as traditional teaching in the classroom Explains and demonstrates how to render the product in the classroom Assign exercise
Students: Product sketch and rendering following the slides	**Students:** Self-practice with MAR-SLS. Product sketch based on the AR system's perspective and then render it for presentation.

At the beginning, the lecturer provided learning materials related to the product sketching, including different products with different texture. Participants from the experimental group used their mobile phones to scan the materials, enabling them to view the 3D view of the product. They were allowed to explore different view of the product by rotating the material. The procedure of the experimental group to experience the system is illustrated as Figure 2. Following the learning session, all participants completed post-tests. These included a knowledge assessment, which was identical to the pre-test but presented in a different sequence, as well as the IMMS questionnaire and the Student Engagement Scale.

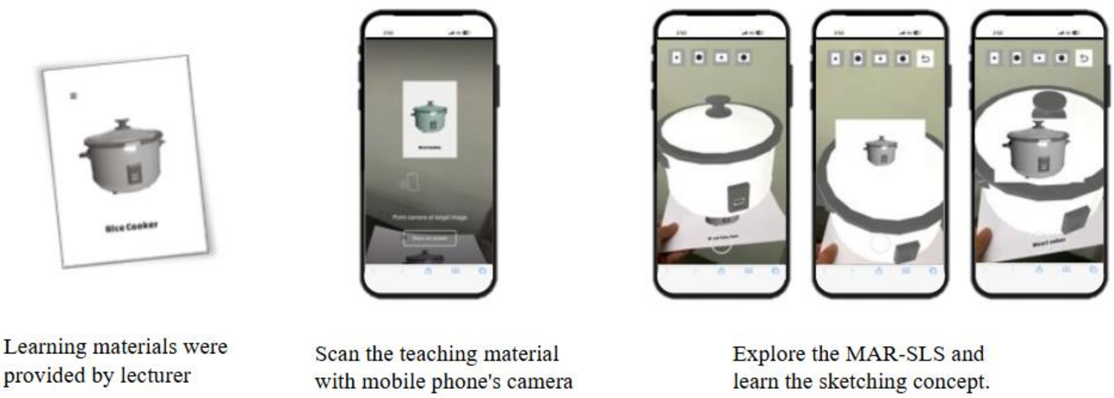

Figure 2: Experiment Procedure in Experimental Group

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Data Collection and Analysis

A pre-test and post-test were administered to assess participants' baseline knowledge of sketching before and after participating in the experiment. These tests included 5 tasks that related to sketching in order to measure their comprehension and practical application. Scoring was given by two senior lecturers from industrial design department. The participants' motivation and engagement were measured using scales based on a 5-point Likert scale. The motivation survey was adapted from the Instructional Material Motivation Survey (IMMS) from Keller (2010), which included 19 questions related to attention, relevance, confidence, and satisfaction. The 13-item Student Engagement Scale (Mazer, 2012) was used to assess their engagement. The motivation and engagement questionnaires were administered to participants after they completed the experiment.

This study used Microsoft Excel to analyse the quantitative analysis for pre-test and post-test questionnaires across three research questions. Student's t-tests were conducted to analyse the relationship between the AR learning system on students' performance, motivation and engagement.

Results

Students' Performance

The results of the t-test comparing the pre-test and post-test scores of students' learning performance are summarized in Table 2. From the table, it can be seen that there was no significance difference between the control group and experimental group in their prior knowledge. The result indicates that participants from both the experimental and control groups were the same level before the intervention of experiment. An independent-samples t-test was then conducted to compare the learning performance of the students. The 24 participants from the experimental group (M = 57.88, SD = 5.27) compared to the 24 participants in the control group (M = 54.17, SD = 4.85) demonstrated significantly better performance scores, $t(46)$ = 2.536, p = .015. These results suggest that the MAR-SLS system had a positive effect on students' learning performance. This provides strong empirical support for research question: *"How does MAR influence student performance in industrial design education, specifically in sketching and rendering tasks?"*

Table 2: Comparison Of Pre-Test and Post-Test Scores Between Experimental and Control Groups

	EXP M	SD	CTR M	SD	t	df	Sig.	95% CI lower	upper
Pre-test	46.63	4.34	44.79	5.12	1.33	46	0.191	0.948	4.614
Post-test	57.88	5.26	54.17	4.85	2.53	46	0.015**	0.765	6.651

Abbreviations *M* mean; *SD* standard deviation; *EXP* experimental group; *CTR* control group
Note **$p<0.05$

Motivation and Engagement

An independent-samples t-test was conducted to compare the motivation, which included four factors Attention, Confidence, Satisfaction, and Relevance, for experimental and control groups respectively. Table 3 presents the summary statistics for the scores of students' motivation with the four factors.

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The experimental group outperformed the control group across all dimensions of learning motivation, as measured by the IMMS (Attention, Relevance, Confidence, and Satisfaction). Specifically, in the Attention dimension, the experimental group achieved significantly higher scores (M = 3.83, SD = 0.19) compared to the control group (M = 2.76, SD = 0.25), $t(46) = 16.87$, $p < .001$, indicating a greater willingness to stay focused during class. Similarly, for the Confidence dimension, the experimental group scored notably higher (M = 4.01, SD = 0.31) than the control group (M = 2.80, SD = 0.29), $t(46) = 13.68$, $p < .001$, suggesting that students felt more assured and capable in engaging with classroom tasks. In terms of Satisfaction, the experimental group reported significantly higher levels (M = 4.04, SD = 0.34) compared to the control group (M = 2.95, SD = 0.36), $t(46) = 10.75$, $p < .001$, implying a greater overall enjoyment with the learning experience. Lastly, for the Relevance dimension, the experimental group also demonstrated higher scores (M = 3.85, SD = 0.27) relative to the control group (M = 3.01, SD = 0.27), $t(46) = 10.56$, $p < .001$, reflecting a stronger perception of the course's applicability to their academic and professional goals.

These findings, summarized in Table 3, provide strong evidence in response to the research question: *"How does augmented reality influence student motivation in industrial design education?"* Overall, the results affirm that integrating AR technology into the curriculum has a significant positive impact on student motivation, particularly by enhancing attention, confidence, satisfaction, and perceived relevance of the course content.

Table 3: T-Tests Result of The Scores of Students' Motivation Related to Attention, Confidence, Satisfaction, And Relevance Dimensions

	EXP M	SD	CTR M	SD	t	df	Sig.	95% CI lower	95% CI upper
AD	3.83	0.19	2.76	0.25	16.87	46	<0.01***	0.94	1.19
CD	4.01	0.31	2.80	0.29	13.68	46	<0.01***	1.03	1.59
SD	4.04	0.34	2.95	0.36	10.75	46	<0.01***	0.89	1.30
RD	3.85	0.27	3.01	0.27	10.56	46	<0.01***	0.68	1.00

Abbreviations *M* mean; *SD* standard deviation; *EXP* experimental group; *CTR* control group.
*AD a*ttention dimension; *CD* confidence dimension; *SD* satisfaction dimension; *RD* relevance dimension.
Note ***p<0.01

Regarding student engagement, the experimental group demonstrated significantly higher levels of engagement (M=3.44, SD=0.14) compared to the control group (M = 2.76, SD = 0.15; $t(46) = 15.58$, $p < 0.001$). This substantial difference suggests that the MAR-SLS enhanced learning environment facilitated deeper involvement in classroom activities. As shown in Table 4, these findings address the research question: *"How does augmented reality impact student engagement in industrial design education?"* The results indicate that incorporating AR technology into the curriculum effectively increases students' active participation and concentration during instructional sessions.

Table 4: T-Tests Result of The Scores of Students' Engagement

	EXP M	SD	CTR M	SD	t	df	Sig.	95% CI lower	95% CI upper
SES	3.44	0.14	2.76	0.15	15.58	46	<0.01***	0.59	0.76

Abbreviations *M* mean; *SD* standard deviation; *EXP* experimental group; *CTR* control group; *SES* student engagement scale.
Note **p<0.05

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Discussion

This study developed and implemented a mobile Augmented Reality learning system (MAR-SLS) with the aim of enhancing spatial understanding and supporting more confident sketching among industrial design students. By offering interactive 3D model manipulation, perspective-based viewing, and sketching aids, the system provided learners with a more immersive and flexible approach to understanding product form and structure.

The findings demonstrated that students who used MAR-SLS showed significantly higher levels of performance, engagement, and motivation compared to those who used traditional multimedia courseware. These results align with previous research suggesting that AR technologies can positively influence learners' motivation and comprehension by offering realistic, hands-on experiences (Faria & Miranda, 2023; Garzón et al., 2019). In particular, the MAR-SLS helped students bridge the gap between theoretical knowledge and practical application, reinforcing the idea that MAR can improve students' ability to visualize and render three-dimensional objects (Trice & Hokanson, 2019). By enabling students to translate 3D spatial concepts into accurate 2D sketches, MAR-SLS supported the development of critical design skills.

The mobile-based delivery of the MAR-SLS can provide interactive and immersive environments for students and help them better comprehend perspective correctness, alignment, and dimensions, which are essential components of industrial design sketching. The interactive experience of MAR-SLS significantly enhances their abilities and enriches their understanding in 1-point, 2-point, and 3-point perspectives rather than depending simply on 2D sketching. By learning to sketch products from diverse angles such as eye level, bird's-eye view, and isometric view, students gain valuable insights into perspective, lighting, and shading. Meanwhile, it also highlights the real-time simulation of displaying the 3D model on either landscape or portrait paper layouts, simulating the sketching environment on actual drawing sheets. These functionalities align seamlessly with those from another research, indicating that AR enables real-time exploration of three-dimensional models, animations, and simulations, fostering deeper understanding and practical skills (Ibáñez & Kloos, 2018; Ding et al., 2024; Li et al., 2024; Rasli & Rasalingam, 2024). Ultimately, these experiences prepare them for real-world applications in the dynamic design industry.

Moreover, the increased engagement observed in this study supports existing literature indicating that interactive MAR environments foster active participation and sustained interest in learning activities (Huey et al., 2024; Carrera et al., 2018). In the current study, experimental group students experienced this firsthand by using mobile devices to scan teaching materials provided by lecturer, which triggered interactive AR content that enhanced their understanding. Thus, students are paying more attention to what they are learning and are more confident in the way they are learning it, making learning more relevant and meaningful. As a result, students were more attentive and felt more in control of their learning, recognizing the direct applicability of their coursework to real-world industrial design challenges.

Importantly, these findings also demonstrate the accessibility and scalability of mobile AR tools, which can be implemented without requiring expensive equipment, making them feasible for a variety of educational settings. From a pedagogical perspective, this suggests that MAR technology has strong potential to support learner-centered instruction, particularly in fields that demand high levels of spatial reasoning and visual literacy. However, successful

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integration also requires appropriate pedagogical strategies and training to ensure that the technology complements fundamental teaching practices. Moving forward, educators and researchers must continue to explore and expand the boundaries of AR technology to unlock its full potential in diverse educational contexts.

Limitations

While this research highlights the significant potential of augmented reality (AR) in enhancing industrial design education, there are limitations that should be considered. Firstly, the findings of this study are based on a specific experimental group from a college in Johor, which may limit their generalizability to a broader student population. Secondly, the focus on a particular subject—such as product sketching—could restrict the applicability of the results to other disciplines where AR might function differently. Additionally, technical challenges may also impede the seamless integration of AR into existing educational systems. In addition, the study does not explore the long-term effects of AR-based learning on students' performance, leaving it as a potential area for further investigation. As a result of these limitations, further research is needed to refine and expand the understanding of how AR can be applied to industrial design education.

Conclusion

Integrating Augmented Reality (AR) technology into design education offers a valuable opportunity to merge traditional sketching techniques with contemporary digital tools, enhancing students' adaptability and effectiveness as future designers. This study successfully achieved its research objectives, demonstrating that the mobile AR-based learning system (MAR-SLS) positively impacts students' learning outcomes in product sketching courses. The system empowered learners to better understand spatial relationships, engage more deeply with the subject matter, and gain confidence in their sketching abilities.

Lastly, as technology continues to evolve, the role of AR in industrial design education will likely expand, offering new and inventive ways to connect with learners. Therefore, it is essential for educators to stay informed about the latest advancements in AR and consider how to effectively incorporate these technologies into their teaching approaches to remain competitive in the ever-changing design field.

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