EDUCATIONAL SCIENCES: THEORY & PRACTICE eISSN: 2148-7561, ISSN: 2630-5984

Received: 02 February 2025
Revision received: 15 March 2025
Accepted: 18 March 2025

www.jestp.com

DOI 10.12738/jestp.2025.1.08 ♦ **January** 2025 ♦ 25(1) ♦ 94-104

Article

Integrating Augmented Reality to Improve Technical Drawing Teaching and Learning Outcomes

Somporn Vongpeang
Rajamangala University of Technology Thanyaburi, Faculty of Technical Education, Thailand.
ORCID iD: https://orcid.org/0009-0009-9473-5158
Email: somporn_v@rmutt.ac.th

Anyarat Sonsanam*
Rajamangala University of Technology Thanyaburi, Faculty of Technical Education, Thailand.
ORCID iD: https://orcid.org/0009-0005-0371-5372
Email: anyarat_p@rmutt.ac.th

Tanut Sripanom
Rajamangala University of Technology Thanyaburi, Faculty of Technical Education, Thailand.
ORCID iD: https://orcid.org/0009-0003-5520-4596
Email: tanutt_s@rmutt.ac.th

Abstract

The design and incorporation of a three-dimensional (3D) object training module based on projection drawing plays a vital role in enhancing students' spatial visualisation abilities. The primary goal is to make instruction in technical drawing more effective by employing Unity 3D in conjunction with Vuforia. This study focuses on constructing a 3D object framework for projection drawing and seeks to produce a pedagogical tool that enables learners to grasp projection processes through an application, thereby strengthening the teaching of technical drawing courses. In addition, the researchers integrated principles of media-based training within projection drawing instruction, assisting students in overcoming challenges when interpreting views from multiple perspectives during technical drawing sessions. The development involved producing an application via Unity 3D that realistically replicates both two-dimensional (2D) and 3D representations, while also being synchronised with Vuforia. The application was configured for exportability, ensuring compatibility with platforms such as Windows and Android, and enabling installation on smartphones. To minimise errors, the researchers collected expert evaluations using a structured quality assessment instrument completed by three specialists. The resulting data were subjected to statistical analysis, employing mean values and standard deviation measures. The assessment revealed reliability levels through the Index of Item Objective Congruence (IOC), with scores between 0.6 and 1 across 20 items, all exceeding the benchmark value of 0.5. These findings confirm that the projection drawing training module attained favourable quality ratings.

Keywords

Augmented Reality, 3D Object Based Training, Visualization Skills, Drawing, Efficiency, Active Learning.

Correspondence to Anyarat Sonsanam, Rajamangala University of Technology Thanyaburi, Faculty of Technical Education, Thailand.
ORCID iD: https://orcid.org/0009-0005-0371-5372, Email: anyarat_p@rmutt.ac.th

Citation: Vongpeang, S., Sonsanam, A., & Sripanom, T. (2025). Integrating Augmented Reality to Improve Technical Drawing Teaching and Learning Outcomes. *Educational Sciences: Theory and Practice, 25*(1), 94 - 104.
http://dx.doi.org/10.12738/jestp.2025.1.08

Introduction

Educational innovation encompasses novel approaches designed either to address challenges in teaching or to enhance learner development for more effective education. Such innovation may involve ideas, frameworks, methods, procedures, and diverse forms of educational media (Perifanou, Economides, & Nikou, 2023). Within instructional practice, media function as channels through which knowledge, skills, and experiences are transferred from the source to the learner, thereby facilitating meaningful learning. Educational media act as supportive instruments for both teachers and students, enabling clearer communication of subject matter and reinforcing understanding. They represent easily accessible learning pathways, allowing learners to engage actively with content. The integration of educational technology into teaching increases the appeal of instructional material and fosters greater interaction between educators and students. Even under circumstances requiring individuals to remain within their residences, such technology supports uninterrupted learning, alleviates restrictions of time and distance, and grants access to extensive academic resources that learners can independently explore.

Historically, teaching methods relied largely on textbook-based lectures. Viewing static illustrations or completed work often resulted in disengagement and a lack of motivation among students. Augmented Reality (AR) has emerged as a technological advancement that merges the physical and virtual realms, allowing screen-based images to appear as three-dimensional forms projected over actual surfaces. Incorporating AR into classrooms enables remote participation, permitting students to observe learning materials from multiple perspectives. AR enhances interactivity, strengthens connections between learners and content, and provides experiential opportunities that stimulate diverse skills and abilities. For example, learners may examine internal structures of the human body or explore mechanical systems virtually.

Consequently, AR serves as a cost-effective educational resource. Empirical evidence has demonstrated that an online training programme in basic occupational health and safety achieved its objectives, with participants showing statistically significant improvement in post-training performance at the 0.01 level. Building upon such findings, this study aims to develop a projection drawing training module employing Unity 3D, with the intention of making learning more engaging, ensuring knowledge retention, and promoting self-directed study.

Research Objectives

1. To design and construct a training package based on 3D object technology for use in drafting instruction.
2. To evaluate the effectiveness of the 3D object-based training package in supporting drafting education.

Conceptual Framework

The conceptual framework for this study is presented in Figure 1. The diagram outlines the effect of applying a 3D object-based training kit within the teaching of technical drafting. It demonstrates how the adoption of 3D technology can enhance instructional quality by offering more engaging and visually enriched learning experiences. From this approach, three principal outcomes are projected: improved efficiency in teaching technical drawing, stronger learning achievement among students, and higher levels of learner satisfaction. The framework emphasises the direct link between the integration of advanced technological resources into teaching practice and the resulting academic and affective gains, ultimately supporting more effective and rewarding learning in technical fields.

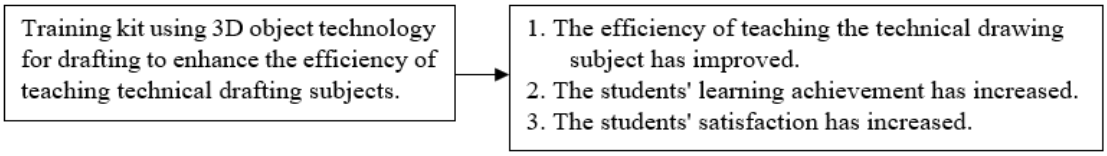

Figure 1: *Conceptual Framework of the Research.*

Research Hypothesis

H1: A training kit with 3D object technology for drafting can increase the efficiency of teaching technical

drafting subjects.

H2: After using the 3D object technology training kit for drawing in teaching, the students' academic achievement improved.

Research Methodology

This study adopts an experimental approach with the objective of designing a projection drawing training set through the Unity 3D application. The research process comprised three main stages: identifying and analysing the problem context, constructing and refining the projection drawing training set using Unity 3D, and assessing its effectiveness through expert evaluation. The investigation was conducted over a twelve-month period, from 1 December 2023 to 30 November 2024.

Population and Sample

A questionnaire was distributed to three experts, who evaluated the quality of the training kit across several dimensions: content, instructional materials, practice sheets, and accompanying manuals. In addition, the alignment of the test items with the intended behavioural objectives was examined using the Index of IOC.

Research Tools

This study adopted a quality assessment approach involving three experts who examined both the test and the projection drawing worksheet. The procedures and data collection process were carried out in the following sequence:

1. The curriculum was reviewed and the subject 'Technical Drawing on Projection Images' was analysed. This stage included clarifying curriculum objectives, defining training topics, establishing training objectives, and setting evaluation criteria, in order to design lessons suitable for trainees.
2. The instructional content was structured by dividing lessons into topics that ensured comprehensive coverage of the subject matter within the allocated training period.
3. A test and a 3D projection drawing worksheet were produced using the SolidWorks program.
4. The images generated in SolidWorks were employed to construct an application through Unity 3D.
5. The quality of the training tools, particularly the projection drawing training set created with Unity 3D, was evaluated by experts.
6. Experts further assessed the alignment between test items and learning objectives using the Item-Objective Congruence (IOC) method.
7. The evaluation outcomes were applied to determine the overall quality of the projection drawing training set, with IOC values analysed to establish the level of consistency between the test items and the stated objectives. The findings were then summarised accordingly.

General Information Questionnaire and Knowledge Test

The questionnaire accompanying the application user manual employed a five-point Likert scale with the following levels: Most, More, Moderate, Less, and Least. The instruments used to assess the quality of the projection drawing training set developed through Unity 3D comprised: 1) Knowledge sheets, 2) Instructional media (PowerPoint 2021), 3) Pre- and post-training tests, 4) Performance assessment sheets, and 5) A training evaluation form. For instrument quality control, the researcher examined existing literature and research reports to identify relevant theories, concepts, and principles, and subsequently applied a structured quality assessment form to evaluate the tools. The process involved:

1. Submission of the questionnaire to experts for validation of content accuracy;
2. Calculation of the Index of Item-Objective Congruence (IOC) using the training set quality assessment form, retaining only those items with an average IOC score of 0.50 or higher.

Following expert feedback, the questionnaire was revised to improve item clarity and relevance, which strengthened content validity and produced higher IOC values. The research design was implemented in three phases to ensure systematic development, implementation, and evaluation. Phase 1 investigated existing challenges in the teaching of projection drawing. Phase 2 concentrated on constructing the instructional tools,

including the experimental materials—specifically the Unity 3D-based projection drawing training set—and the instruments for data collection. Phase 3 focused on evaluating the effectiveness of the developed training set. The cycle of development, evaluation, revision, and analysis of the Unity 3D-based training set followed a series of structured steps: Expert review of the Unity 3D projection drawing training set; Data collection and analysis conducted before and after its implementation; Subsequent revision of the training set based on empirical findings; and the final synthesis of experimental outcomes.

Data Analysis

The quality of the analytical instrument was evaluated using fundamental statistical indices. These included the arithmetic mean (Mean), which represents the central tendency of responses, and the standard deviation (S.D.), which indicates the degree of dispersion of the data around the mean.

$$\bar{x} = \frac{\sum x}{N}$$

Where: $\bar{x}$ = Mean
X = Individual Score
N = Number of Students in the Sample

Standard Deviation S.D = $\frac{\sum_k^n (xi-\bar{x})}{N}$

Where: $\bar{x}$ = Mean of the Sample
X = Individual Data Value or the Midpoint of Each Class
N = Number of Students in the Sample
S.D = Standard Deviation of the Sample

The interpretation of mean scores was classified into four levels: scores between 3.50 and 4.00 were regarded as reflecting the highest quality; values ranging from 2.50 to 3.49 indicated high quality; scores within 1.50 to 2.49 represented low quality; and values between 1.00 and 1.49 denoted the lowest quality.

Results and Discussion

The development of the projection drawing training set through the Unity 3D application was undertaken by the researcher as a specialised instructional tool. To evaluate its quality, assessments were obtained from three experts. The analysis of the quality assessment form was carried out using mean and standard deviation. The study's findings include two main aspects: the expert evaluations of the overall quality of the training set, and the results concerning the consistency between the test items and the intended behavioural objectives, measured through the Index of IOC.

The Training Kit Quality Assessment by Experts

The projection drawing training set was developed by the researcher through the Unity 3D application. To determine its quality, feedback was obtained from three experts using a structured quality assessment form. The evaluations were then analysed using mean and standard deviation, with the outcomes presented in Table 1 and Figure 1.

Content: From Table 1, the results of the training set quality evaluation by experts revealed that the projection drawing training set developed with the Unity3D application achieved an overall mean score of 3.94 (S.D. = 0.23), which is classified as "good." Within this category, the consistency of the content with the objectives obtained a mean score of 4.33 (S.D. = 0.58). The sequence of the content presentation received a mean score of 4.00 (S.D. = 0.00). The accuracy of the content, as well as the clarity of its explanation, each obtained a mean score of 3.33 (S.D. = 0.58). Meanwhile, the consistency of the content across individual items scored the highest with a mean of 4.67 (S.D. = 0.58). Teaching Media Aspect: The evaluation of the teaching media aspect showed positive results. The appropriateness of the pictures in relation to the content achieved a mean score of 4.33 (S.D. = 0.58). The consistency of the pictures with the captions was rated at 4.00 (S.D. = 0.00). The appropriateness and correctness of the language used scored 3.67 (S.D. = 0.58). The use of colour was evaluated as highly suitable, with a mean score of 4.33 (S.D. = 0.58). However, the accuracy of spelling and punctuation was rated lower, with a mean score of 3.33 (S.D. = 0.58).

Dimensions of the Test Sheet: For the test sheet dimension, the consistency of the content with the objectives, as well as the comprehensiveness of the tools list, both achieved mean scores of 4.33 (S.D. = 0.58). The materials and equipment, together with worksheet accuracy, were each rated at 4.00 (S.D. = 0.00). In contrast, clarity in explaining the worksheet content received a lower evaluation, with a mean score of 3.33 (S.D. = 0.58).

Manual Aspects: The manual was also positively assessed. Its size was considered appropriate and compact, with a mean score of 4.00 (S.D. = 0.00). The ease of understanding the content was rated at 3.67 (S.D. = 1.15). The organisation of the content into categories scored 4.00 (S.D. = 0.00), while the sequential and consistent structuring of the material was rated at 3.67 (S.D. = 0.58). Overall satisfaction with the usefulness of the manual received one of the highest scores, at 4.33 (S.D. = 0.58).

Table 1: *Results of the Quality Assessment of the Training Set by Experts.*

Evaluation Criteria	Mean	S.D.	Meaning
1. Content			
Content Consistency with Objectives	4.33	0.58	High Quality
Content Presentation Process	4.00	0.00	High Quality
Content Accuracy	3.33	0.58	Adequate Quality
Clarity in Explaining the Training Package Content	3.33	0.58	Adequate Quality
Content Consistency Across Each Topic	4.67	0.58	Highest Quality
2. Teaching Media			
The Appropriateness of the Images to the Content of the Story	4.33	0.58	High Quality
The Consistency of the Images with the Captions in the Content	4.00	0.00	High Quality
The Language used is Appropriate and Accurate	3.67	0.58	High Quality
The Use of Colours in the Content is Appropriate	4.33	0.58	High Quality
The Correctness of Spelling and Punctuation	3.33	0.58	Adequate Quality
3. Test Sheet			
Content Consistency with Objectives	4.33	0.58	High Quality
List of Tools, Materials, and Equipment	4.33	0.58	High Quality
Accuracy of the Worksheet	4.00	0.00	High Quality
Clarity in Explaining the Content of the Worksheet	3.33	0.58	Adequate Quality
4. Manual			
The Size of the Manual is Appropriate and Compact	4.00	0.00	High Quality
The Content of the Manual is Easy to Understand	3.67	1.15	High Quality
The Content is Organized into Categories, making it Easy to Follow	4.00	0.00	High Quality
The Content is Structured in Steps, Consistent, and Well-Connected	3.67	0.58	High Quality
Overall Satisfaction with the Benefits Received from this Manual	4.33	0.58	High Quality
Total	3.94	-	High Quality

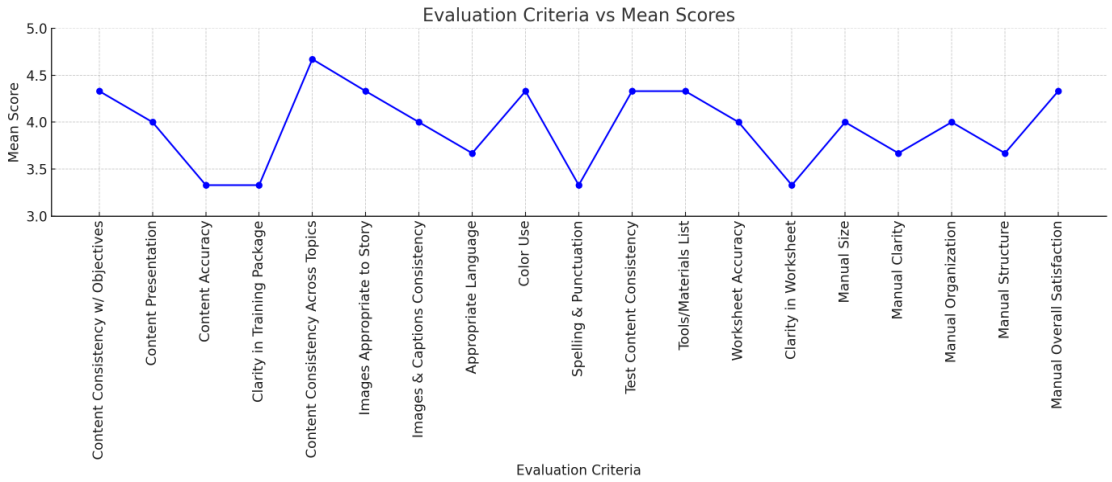

Figure 2: *Evaluation Criteria vs Mean Scores.*

Analysis of the Consistency of the Test with the Behavioural Objectives (IOC)

Based on Table 2, the evaluation of expert opinions was analysed using the values of IOC (Item Objective Congruence). The findings revealed that the IOC values for the 20 items ranged from 0.6 to 1.0, demonstrating that all items met the required standard for use. Following this analysis, the researcher refined the items further in line with the additional recommendations provided by the experts Figure 2.

Table 2: *Results of the Analysis of the Consistency of the Test Items with the Behavioural Objectives (IOC).*

No.	Expert Rating Level			Total	Average	Evaluation Results
	Person 1	Person 2	Person 3			
1	1	1	1	3	1.00	Appropriately
2	1	1	1	3	1.00	Appropriately
3	1	1	1	3	1.00	Appropriately
4	1	1	1	3	1.00	Appropriately
5	1	0	1	2	0.67	Appropriately
6	1	1	1	3	1.00	Appropriately
7	1	1	1	3	1.00	Appropriately
8	1	1	1	3	1.00	Appropriately
9	1	1	1	3	1.00	Appropriately
10	1	0	1	2	0.67	Appropriately
11	1	1	1	3	1.00	Appropriately
12	1	1	1	3	1.00	Appropriately
13	1	1	1	3	1.00	Appropriately
14	1	1	1	3	1.00	Appropriately
15	1	1	1	3	1.00	Appropriately
16	1	0	1	2	0.67	Appropriately
17	1	1	1	3	1.00	Appropriately
18	1	1	1	3	1.00	Appropriately
19	1	1	1	3	1.00	Appropriately
20	1	1	1	3	1.00	Appropriately

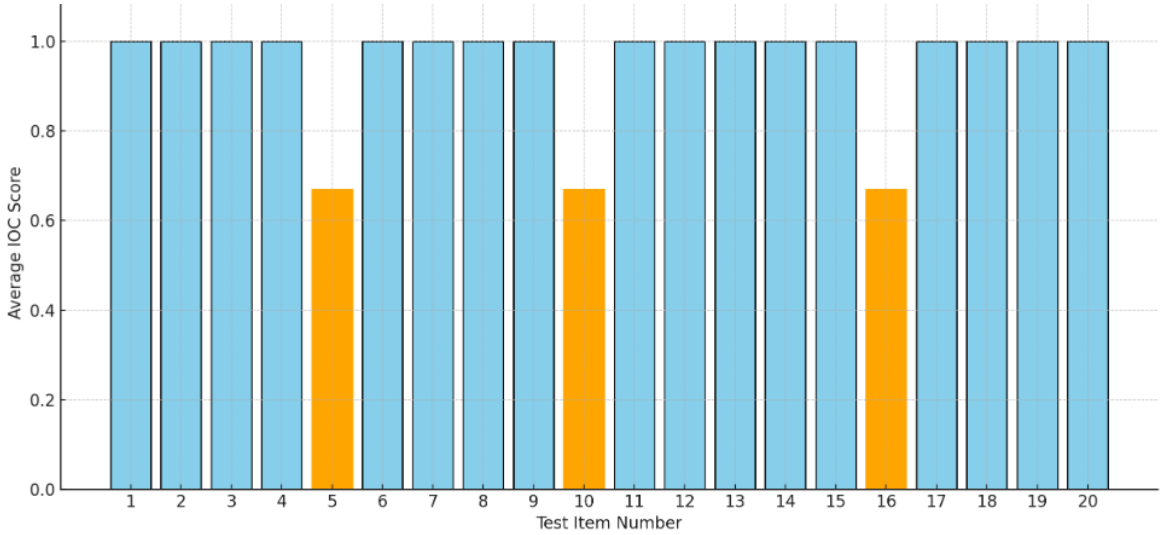

Figure 3: *IOC Scores Per Test Item.*

The design of the projection drawing training kit within the Unity 3D application, accompanied by a comprehensive manual, represents a significant advancement in enhancing the effectiveness of technical drawing instruction. The instructional materials incorporate theoretical concepts, symbol interpretation, and structured assessments, including pre- and post-training tests, providing a balanced approach that fosters both conceptual

understanding and practical application (Jia, 2024). The robustness of these instructional resources is further substantiated by the use of the IOC method to evaluate the quality and appropriateness of the test items. All 20 items achieved IOC values ranging from 0.6 to 1.0, surpassing the established threshold of 0.5, indicating that each component was validated as suitable for assessing learning outcomes. This alignment confirms that the training kit and associated evaluation tools are consistent with the instructional objectives and are applicable in practical teaching scenarios (Gokbulut & Durnali, 2023).

Thepprasit and Chaichomchuen (2018) examined the structure and components of a teacher training set designed using a project-based program on the Scratch platform, evaluated by five experts to enhance programming competency. Their findings indicated that the training set format was highly appropriate ($\bar{X} = 4.36$, S.D. = 0.68), comprising three main elements: input factors, the training process, and outcomes. The training process itself encompassed seven stages: pre-training competency assessment, trainee orientation, basic knowledge provision, design and planning, project development, presentation and evaluation, and post-training competency assessment. This aligns with the study conducted by Samma, Thongchap and Chanaisawan (2017), who developed and evaluated the effectiveness of a submerged arc welding training package based on the Know How Transfer Co., Ltd. competency model, involving 15 participants during 2015–2016. Their results demonstrated that trainee performance averaged 90.40/92.82/91.95 percent, exceeding the pre-established benchmark of 80 percent across all criteria. Post-training knowledge in each topic averaged 84.00 percent, and statistical comparison revealed a significant difference at the 0.01 level, with post-training scores surpassing pre-training outcomes.

In informal apprenticeship models, on-the-job learning predominates, typically without formal pre- or post-training assessments. Such systems provide essential employment opportunities, contribute to youth crime reduction, and generate revenue for local authorities. Socially, these programmes enhance apprentices' self-esteem and social recognition within families and communities. Progress evaluation is usually conducted through continuous observation, with certification granted once skills are deemed sufficient by experienced masters (Korang, 2021). However, behavioural integrity assessments in such contexts are subjective and susceptible to various perceptual biases, as observer interpretations of word–action alignment or discrepancies influence judgments of high or low behavioural integrity (Simons, Leroy, & Nishii, 2022).

Education represents a cross-cutting strategy for fostering a culture of safety among future generations by developing competencies and expanding knowledge. While it cannot fully resolve the objectives of the Sustainable Development Goals, which seek inclusive and equitable quality education and lifelong learning opportunities, education remains a vital component in addressing occupational health and safety through preventive rather than reactive measures (Kavouras et al., 2022). The most effective methods for enhancing risk assessment skills include targeted training, coaching, explicit instructions, and diverse instructional techniques, forming the basis for actionable development plans to improve such competencies (Musungwa & Kowe, 2022; Rantala, Lindholm, & Tappura, 2022).

Furthermore, research has produced an online training package addressing basic occupational health and safety for industrial employees, with a sample of 310 supervisory staff. This supports prior findings by Reid, Ronda-Perez and Schenker (2021) and Segbenya and Yeboah (2022), emphasising that management engagement is critical for occupational safety, with organisational priorities favouring worker health over cost concerns. The development of customised Virtual Reality experiences for specific user groups holds significant promise for advancing safety practices, particularly in construction (Akindele et al., 2024; Gupta et al., 2022). Overall, the positive evaluation outcomes confirm the reliability and validity of the projection drawing training kit, reinforcing its capacity to support learners in acquiring essential skills through digital tools such as Unity 3D. The findings also underscore the broader potential of integrating interactive technologies in technical education to enhance learner engagement and skill development (Estrada et al., 2022; Papakostas et al., 2021).

According to the research objectives, this study aimed to develop a training set using 3D object technology (3DOT) for drafting and to evaluate the efficiency of the developed training set. The results indicated that the online training package on basic occupational health and safety (OHS) met the established criteria for effectiveness. Trainees' academic performance before and after training showed statistically significant differences at the 0.01 level (Spruijt-Metz et al., 2015). Specifically, a projection drawing training kit using the Unity 3D (Unity) application was created to provide an interactive learning environment that enhances students' spatial visualisation and comprehension of technical drawing principles. The accompanying training manual

comprehensively supports learning and assessment, encompassing theoretical content, evaluation instruments, and quality validation of the projection drawing training kit. The manual includes five components: theory of projection drawing, theory of projection drawing symbols, pre-training and post-training tests, performance evaluation criteria, and results of the training kit quality assessment.

Evaluation of the training set was performed using IOC (Item Objective Congruence) values. All 20 items obtained IOC scores ranging from 0.6 to 1.0, exceeding the threshold of 0.5, confirming their suitability for instructional use. Therefore, the Unity-based training kit and its manual were validated as effective tools for teaching projection drawing. The 3DOT training set developed with Unity, integrated with Vuforia technology, demonstrated its effectiveness in enhancing students' understanding of projection drawing, addressing a key challenge in technical drawing education. This integration helped learners overcome common difficulties in visualising complex projection views from multiple angles, in alignment with the study objective of improving learning outcomes through engaging media.

Expert evaluation of the training set produced an overall mean score of 3.94 (S.D. = 0.23). Within the content dimension, consistency with learning objectives scored highly (mean = 4.33), while accuracy and clarity of content (mean = 3.33) indicated areas for further improvement. Teaching media aspects showed strengths in visual consistency and colour application (mean = 4.33), although language precision and typographical accuracy required enhancement. Evaluation of test sheets and manual components also yielded positive outcomes, particularly in aligning content with learning objectives and structuring instructional material. Variability in content clarity scores (mean = 3.33–3.67) highlighted the need for clearer explanations and simplified language to accommodate all learners. The IOC values for all 20 items further support the content validity and appropriateness of the developed instructional tools. Expert feedback guided targeted revisions, improving both instructional accuracy and technical fidelity. These findings demonstrate that the Unity-based training application is a valuable asset for enhancing technical drawing pedagogy. Continuous refinement, particularly in content explanation and language clarity, combined with student-centred usability testing, could further increase its educational impact and scalability across different learning environments.

The incorporation of AR in technical education introduces transformative potential, supporting diverse learner needs and increasing engagement. As evidenced in this study, AR can address educational challenges and improve comprehension of complex concepts. It facilitates enhanced student engagement and motivation, as also noted by Boboc, Chiriac and Antonya (2021), who reported that AR encourages active learning by focusing attention on technical mechanisms. Immersive AR activities provide improved learning experiences, rendering technical drawing exercises more accessible and engaging. Koumpouros (2024) further emphasised that AR extends beyond engagement, enabling learners to visualise and manipulate objects in 3D space, which is essential for acquiring technical drawing competencies.

However, AR implementation is not without challenges. Perifanou et al. (2023) highlighted that effective integration requires sufficient teacher training and institutional support to ensure successful AR-enabled curricula. Additionally, personalising AR for individual learners enhances its educational value. Papakostas et al. (2022) illustrated the use of AR to train spatial abilities according to individual learning needs, demonstrating its utility in technical drawing courses reliant on spatial comprehension. The integration of AR and AI offers further opportunities, allowing adaptive learning experiences and real-time feedback, which could accelerate skill acquisition in technical drawing (Capecchi et al., 2025; Wang et al., 2022). Studies by Díaz González et al. (2025) confirm that interactive virtual reality and AR positively influence conceptual design knowledge in engineering and architecture, reinforcing the relevance of AR in technical drawing education. Koumpouros (2024) suggested further research to optimise AR application practices. Zhang et al. (2024) reviewed literature supporting AR's role in improving visualisation and comprehension in STEM education, validating its use in technical drawing instruction. Furthermore, AR can accommodate diverse learning needs, including students with ADHD or reading and spelling difficulties, as demonstrated by Tosto et al. (2021). Such flexibility ensures that learners who struggle with conventional technical instruction can still acquire essential skills.

The growing adoption of AR in educational practice aims to enhance learning processes. Perifanou et al. (2023) emphasised the importance of teacher attitude, training, and resources for successful AR integration. Wang et al. (2024) highlighted rural educators' interest in AR to reduce educational disparities, stressing the need for contextualised content. Evidence also shows AR's effectiveness in specific domains such as grammar and geometry, with Safar, Al-Jafar and Al-Yousefi (2016) and Rossano et al. (2020) demonstrating

improvements in engagement, comprehension, and simplification of abstract concepts. Current trends suggest that AR has evolved from a visualisation tool to a personalised, adaptive learning medium, as illustrated by Papakostas et al. (2022). Nevertheless, challenges remain regarding educator training and technological infrastructure, which are essential to fully realise AR's educational potential (Young, O'Dwyer, & Smolic, 2022).

Zhang et al. (2024) conducted an umbrella review on the application of virtual reality (VR) and AR in STEM education, emphasising the need for future research to evaluate the long-term effectiveness of these technologies in achieving educational objectives. Similarly, Tadesse and Muluye (2020) highlighted pressing challenges in education systems, particularly in developing countries during the COVID-19 pandemic, when the flexibility provided by technological adoption became critical. In this context, AR can serve as a resilience tool within education, offering the potential to mitigate limitations associated with conventional learning methods. In conclusion, while the benefits of AR in education are evident, successful implementation requires careful attention to teacher preparation, infrastructure provision, and pedagogical integration. Moreover, coordinated efforts among educators, technology specialists, and policymakers are crucial to fully harness the potential of AR and VR for enhancing learning outcomes across diverse educational settings (Díaz González et al., 2025; Yu, 2023).

Limitations

The version of SolidWorks employed was outdated and lacked compatibility with file extensions required by the Unity 3D (Unity) program. Furthermore, the drawing process within the Unity application experienced errors caused by limitations in the software used for developing the application.

Suggestions

1. This study has certain limitations concerning projective drawing, rendering it impractical to test across all subject areas. Consequently, the researcher focused exclusively on a single subject, application control, for testing purposes. Other untested aspects should be examined prior to the broader application of the research findings.
2. For an effective evaluation of the quality of the projective drawing training kit developed with the Unity 3D (Unity) application, instructors are required to have a thorough understanding of the training manual, competency assessment procedures, and training content. Such knowledge will ensure that trainees achieve optimal outcomes and can transfer the acquired skills effectively into their professional practice.

Conclusion

The study findings highlight the effectiveness of integrating AR with 3DOT to enhance the teaching and learning of technical drawing. The Unity application, combined with Vuforia technology, provides an interactive training environment that improves students' visualisation skills in projection drawing. Positive evaluations from experts, with IOC values ranging from 0.6 to 1.0, confirm the quality of the training set and its alignment with educational objectives. This research carries significant implications for educators and curriculum developers. The integration of AR and 3DOT can transform educational practices, address the needs of contemporary learners and render complex concepts more accessible and engaging. The findings suggest that this innovative approach can increase student motivation, deepen comprehension of technical principles, and ultimately improve academic performance. Additionally, the ability to manipulate 3D objects from multiple angles addresses a known limitation in technical drawing pedagogy, where traditional methods often create a disconnect between theoretical knowledge and practical application. However, there remains a scarcity of longitudinal studies, indicating the need for future research to examine the long-term effects of AR integration on learning outcomes and knowledge retention. Investigating the use of AR across different subjects could provide broader insights into its versatility and applicability. Furthermore, exploring how AR interacts with specific learner populations may extend the application of 3DOT and AR to specialised educational strategies that account for demographic and cognitive variations. Continued research into AR-based learning is likely to enhance both interactivity and engagement, ultimately improving the overall effectiveness of educational processes.

References

Akindele, N., Taiwo, R., Sarvari, H., Oluleye, B. I., Awodele, I. A., & Olaniran, T. O. (2024). A state-of-the-art analysis of virtual reality applications in construction health and safety. *Results in Engineering, 23*, 102382. https://doi.org/10.1016/j.rineng.2024.102382

Boboc, R. G., Chiriac, R.-L., & Antonya, C. (2021). How Augmented Reality Could Improve the Student's Attraction to Learn Mechanisms. *Electronics, 10*(2), 175. https://doi.org/10.3390/electronics10020175

Capecchi, I., Borghini, T., Bellotti, M., & Bernetti, I. (2025). Enhancing Education Outcomes Integrating Augmented Reality and Artificial Intelligence for Education in Nutrition and Food Sustainability. *Sustainability, 17*(5), 2113. https://doi.org/10.3390/su17052113

Díaz González, E. M., Belaroussi, R., Soto-Martín, O., Acosta, M., & Martín-Gutierrez, J. (2025). Effect of Interactive Virtual Reality on the Teaching of Conceptual Design in Engineering and Architecture Fields. *Applied Sciences, 15*(8), 4205. https://doi.org/10.3390/app15084205

Estrada, J., Paheding, S., Yang, X., & Niyaz, Q. (2022). Deep-Learning-Incorporated Augmented Reality Application for Engineering Lab Training. *Applied Sciences, 12*(10), 5159. https://doi.org/10.3390/app12105159

Gokbulut, B., & Durnali, M. (2023). Professional skills training in developing digital materials through augmented and virtual reality applications. *Psychology in the Schools, 60*(11), 4267-4292. https://doi.org/10.1002/pits.22991

Gupta, Y. P., Chawla, A., Pal, T., Reddy, M. P., & Yadav, D. S. (2022). 3D Networking and Collaborative Environment for Online Education. In *2022 10th International Conference on Emerging Trends in Engineering and Technology-Signal and Information Processing (ICETET-SIP-22)* (pp. 1-5). IEEE. https://doi.org/10.1109/ICETET-SIP-2254415.2022.9791699

Jia, X. (2024). Design and teaching application of a virtual simulation training system for bridge engineering drawing recognition based on Unity3D. *Archives of Civil Engineering, 70*(3), 487-498. https://doi.org/10.24425/ace.2024.150997

Kavouras, S., Vardopoulos, I., Mitoula, R., Zorpas, A. A., & Kaldis, P. (2022). Occupational Health and Safety Scope Significance in Achieving Sustainability. *Sustainability, 14*(4), 2424. https://doi.org/10.3390/su14042424

Korang, V. (2021). Apprenticeship Skills Development within the Informal Sector of the Ghanaian Economy: The Case of Sunyani Magazine. *UDS International Journal of Development, 8*(1), 559-572. https://doi.org/10.47740/564.UDSIJD6i

Koumpouros, Y. (2024). Revealing the true potential and prospects of augmented reality in education. *Smart Learning Environments, 11*(1), 2. https://doi.org/10.1186/s40561-023-00288-0

Musungwa, T., & Kowe, P. (2022). Effects of occupational health and safety management systems implementation in accident prevention at a Harare beverage company. *Cogent Engineering, 9*(1), 2124638. https://doi.org/10.1080/23311916.2022.2124638

Papakostas, C., Troussas, C., Krouska, A., & Sgouropoulou, C. (2021). On the Development of a Personalized Augmented Reality Spatial Ability Training Mobile Application. In *Novelties in Intelligent Digital Systems* (pp. 75-83). IOS Press. https://doi.org/10.3233/FAIA210078

Papakostas, C., Troussas, C., Krouska, A., & Sgouropoulou, C. (2022). Personalization of the Learning Path within an Augmented Reality Spatial Ability Training Application Based on Fuzzy Weights. *Sensors, 22*(18), 7059. https://doi.org/10.3390/s22187059

Perifanou, M., Economides, A. A., & Nikou, S. A. (2023). Teachers' Views on Integrating Augmented Reality in Education: Needs, Opportunities, Challenges and Recommendations. *Future Internet, 15*(1), 20. https://doi.org/10.3390/fi15010020

Rantala, M., Lindholm, M., & Tappura, S. (2022). Supporting Occupational Health and Safety Risk Assessment Skills: A Case Study of Five Companies. *International Journal of Environmental Research and Public Health, 19*(3), 1720. https://doi.org/10.3390/ijerph19031720

Reid, A., Ronda-Perez, E., & Schenker, M. B. (2021). Migrant workers, essential work, and COVID-19. *American Journal of Industrial Medicine, 64*(2), 73-77. https://doi.org/10.1002/ajim.23209

Rossano, V., Lanzilotti, R., Cazzolla, A., & Roselli, T. (2020). Augmented Reality to Support Geometry Learning. *IEEE Access, 8*, 107772-107780. https://doi.org/10.1109/ACCESS.2020.3000990

Safar, A. H., Al-Jafar, A. A., & Al-Yousefi, Z. H. (2016). The Effectiveness of Using Augmented Reality Apps in Teaching the English Alphabet to Kindergarten Children: A Case Study in the State of Kuwait. *EURASIA Journal of Mathematics, Science and Technology Education, 13*(2), 417-440. https://doi.org/10.12973/eurasia.2017.00624a

Samma, N., Thongchap, C., & Chanaisawan, K. (2017). Construction and Efficiency Evaluation of Submerged Arc Welding in Accordance with Competency Training Set. *Journal of Industrial Studies, 11*(2), 82-95. https://ejournals.swu.ac.th/index.php/jindedu/article/view/9648

Segbenya, M., & Yeboah, E. (2022). Effect of Occupational Health and Safety on Employee Performance in the Ghanaian Construction Sector. *Environmental Health Insights, 16*, 11786302221137222. https://doi.org/10.1177/11786302221137222

Simons, T., Leroy, H., & Nishii, L. (2022). Revisiting Behavioral Integrity: Progress and New Directions After 20 Years. *Annual Review of Organizational Psychology and Organizational Behavior, 9*, 365-389. https://doi.org/10.1146/annurev-orgpsych-012420-062016

Spruijt-Metz, D., Hekler, E., Saranummi, N., Intille, S., Korhonen, I., Nilsen, W., et al. (2015). Building new computational models to support health behavior change and maintenance: new opportunities in behavioral research. *Translational Behavioral Medicine, 5*(3), 335-346. https://doi.org/10.1007/s13142-015-0324-1

Tadesse, S., & Muluye, W. (2020). The Impact of COVID-19 Pandemic on Education System in Developing Countries: A Review. *Open Journal of Social Sciences, 8*(10), 159-170. https://doi.org/10.4236/jss.2020.810011

Thepprasit, R., & Chaichomchuen, S. (2018). The Design of Training Package for Teacher Using Projectbased on Scratch to Develop Competency Coding. *E-Journal of Media Innovation and Creative Education, 1*(1), 35-45. https://ejournals.swu.ac.th/index.php/cemt/article/view/9871

Tosto, C., Hasegawa, T., Mangina, E., Chifari, A., Treacy, R., Merlo, G., et al. (2021). Exploring the effect of an augmented reality literacy programme for reading and spelling difficulties for children diagnosed with ADHD. *Virtual Reality, 25*(3), 879-894. https://doi.org/10.1007/s10055-020-00485-z

Wang, H., Cousineau, C., Wang, B., Zeng, L., Sun, A., Kohrman, E., et al. (2022). Exploring Teacher Job Satisfaction in Rural China: Prevalence and Correlates. *International Journal of Environmental Research and Public Health, 19*(6), 3537. https://doi.org/10.3390/ijerph19063537

Wang, X., Young, G. W., Iqbal, M. Z., & Guckin, C. M. (2024). The potential of extended reality in Rural Education's future – perspectives from rural educators. *Education and Information Technologies, 29*(7), 8987-9011. https://doi.org/10.1007/s10639-023-12169-7

Young, G. W., O'Dwyer, N., & Smolic, A. (2022). Exploring virtual reality for quality immersive empathy building experiences. *Behaviour & Information Technology, 41*(16), 3415-3431. https://doi.org/10.1080/0144929X.2021.1993336

Yu, Z. (2023). A meta-analysis of the effect of virtual reality technology use in education. *Interactive Learning Environments, 31*(8), 4956-4976. https://doi.org/10.1080/10494820.2021.1989466

Zhang, Y., Feijoo-Garcia, M. A., Gu, Y., Popescu, V., Benes, B., & Magana, A. J. (2024). Virtual and Augmented Reality in Science, Technology, Engineering, and Mathematics (STEM) Education: An Umbrella Review. *Information, 15*(9), 515. https://doi.org/10.3390/info15090515