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# Augmented Reality for Collaborative Learning: Enhancing 21st-Century Competencies in Indonesian Design Education

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**Abstract.** Educators currently face the challenge of innovating learning spaces and instructional methodologies with technology to provide their students with 21st-century competencies (collaboration, problem-solving, creative, and critical thinking). Augmented Reality (AR) technology has been shown to positively influence student engagement, but its effectiveness and sustained use still require further investigation. This is also an issue in Indonesian tertiary education, where large classes and a lack of pedagogical support hinder the design of effective technology-supported classrooms. This study investigated the integration of AR technology within a collaborative learning environment, based on Gagne's Nine Events of Instruction as the theoretical framework, and was presented to 50 design students at an Indonesian university. A convergent mixed-method research design was employed, and data were collected using a structured survey, open-ended questions, and student feedback. Descriptive analysis yielded five key areas of student learning experiences: 1) Collaboration and Teamwork, 2) Creativity, Critical Thinking, and Problem-Solving, 3) Knowledge Construction, 4) Enjoyment, and 5) Augmented Reality in the Learning Process. Pearson's correlation coefficient analyses showed strong and positive relationships among all five constructs and were closely aligned with Gagne's Nine Events of Instruction. The resulting ARCLE framework is proposed as a replicable model for integrating AR into emerging educational contexts and cultivating 21st-century competencies in learners in Indonesian design-based education.

**Keywords:** Immersive Learning; AR in Education; Collaborative Learning; Pedagogical Framework; Indonesian Design Education.

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## 1. Introduction

Education in the post-pandemic “new normal” is undergoing a transformation in teaching and learning methodologies from instructional design to content delivery to interaction platforms. There is now a demand for the creation of learning opportunities for students to enhance their learning competencies such as collaboration and teamwork, creativity, problem-solving skills, and critical thinking abilities. As such, educators are now tasked with developing innovative and creative instructional strategies for face-to-face classrooms, online learning modules, virtual learning spaces, and even blended learning approaches (hybrid, integrated, and mixed mode), which can present many challenges in design and delivery (Siddig et al, 2024; Ampo et al., 2025).

Advancements in technology have resulted in a growing demand to integrate it within classroom learning in a blender or online learning context. Studies have shown mixed results regarding its application. Therefore, there is a need to continue the investigation of its effectiveness in educational settings. In addition, digitally savvy and technologically astute learners today find themselves less motivated and inclined to retain information in conventionally taught classes (Guppy et al., 2022; Siddiq et al., 2024). As such, many institutions of higher learning are facing challenges in bridging this digital divide between what students require technologically and what can be provided by educational institutions.

In particular, these include more flexible, technologically advanced, and adaptive learning environments that can be appropriately designed and capable of delivering content effectively to students. In addition, teaching strategies such as collaborative learning have been posited to be effective in promoting enhanced active engagement among students and, when combined with technology, can create a dynamic and interactive learning environment. Currently, emerging technologies such as Virtual Reality (VR), Augmented Reality (AR), and Artificial Intelligence (AI) are being used in classrooms to increase the interactivity and engagement levels among learners (Pelletier et al., 2022; Pelletier et al., 2023).

Integrating AR into the classroom has been shown to foster collaboration, improve understanding of content, increase motivation and affective levels, and provide students with opportunities to develop higher-order learning experiences (Sulistyanto et al., 2024; Adi et al., 2025; Kaviyaraj & Uma, 2025). However, there is still a lack of confidence in implementing such learning environments (Glazunova et al., 2023; Ortega-Arranze et al., 2024; Sandoval-Henriquez et al., 2025). Educators continue to face pedagogical and technological challenges and struggle to foster effective collaborative learning opportunities for their students (Marreh & Velankar, 2024).

There is also a lack of pedagogically grounded AR frameworks investigated in non-Western contexts, such as Indonesia, where resources are scarce. This is especially significant in Indonesian design education, where high student-to-teacher ratios, resistance and lack of teacher training in using technology, and infrastructure issues reduce the overall quality of instruction and student learning

outcomes (Rosser, 2023; Alawi & Sinaga, 2024; Susanti et al., 2024; Carabregu-Vokshi et al., 2024). Therefore, the use of AR in education, especially pedagogically sound AR frameworks, requires further investigation.

This study comprised three primary objectives:

1. Design an immersive and collaborative learning environment that is supported by AR
2. Investigate the impact of Augmented Reality on developing 21st century competences among university students in Indonesia, and
3. Develop a learning framework that would effectively integrate technology (AR) and pedagogy (Gagne's Nine Events of Instruction) for emerging educational contexts.

The study was guided by the following research question: *"How does an AR-supported collaborative learning environment impact student learning experiences in design education?"*. In answering this research question, this study aimed to present a replicable learning framework for the effective implementation of pedagogy, content, and technology in design education.

## 2. Literature Review

### 2.1 Post-pandemic education: The need to cultivate 21st century student competencies in higher education

Over the past few decades, technology-supported learning has created opportunities for innovative teaching and learning methodologies due to its ability to improve student learning (Mustafa et al., 2024). The COVID-19 pandemic caused a significant rise in the integration of technology into classrooms as educators sought to transfer their teaching materials online (Nurhidayat et al., 2024; Siddiq et al., 2024).

Technology integration has transformed the way teachers instruct and how students learn, communicate, and collaborate. There is a need to move away from conventional lecture-based learning and instructor-centred pedagogies to more collaborative, interactive, experiential methods that are supported by technologies. These methods translate into the cultivation of 21st century skills such as collaboration, creativity, critical thinking, and problem-solving among digitally savvy students who demand flexible, authentic, and real-world scenarios that allow them to connect their academic studies with their workplace aspirations (Avdiu et al., 2025).

However, despite this call for technology-supported learning environments, educators still face challenges to keep pace with these technological advancements and continue to rely on conventional teaching and learning strategies that do not actively engage students in meaningful and deep learning. Studies still show that students are finding themselves with mismatched skills in the workplace (Salahuddin et al., 2023; Siddiq et al., 2024; Carabregu-Vokshi et al., 2024). As such, there is a growing demand to design technology-supported learning environments that are meaningful, collaborative, and interactive, that

foster the development of these 21st-century competencies in university graduates (Fang et al., 2023).

## 2.2 The Use of Augmented Reality (AR) in Education

Currently, there is an increasing demand for the integration of VR (Virtual Reality), AR (Augmented Reality), and MR (Mixed Reality) technologies in many disciplines. Horizon Reports of 2022 and 2023 have indicated that emerging technologies provide students with more meaningful learning experiences through their immersive nature and by extending beyond physical spaces into virtual ones (Pelletier et al., 2022; Pelletier et al., 2023).

With these technologies supporting the learning process, students can better meet 21st-century workplace demands and develop critical thinking skills, become active learners and independent thinkers, as posited by Rosser (2023) and Alawi & Sinaga (2024). Kaminska et al. (2023) have suggested that Augmented Reality (AR) is becoming more prevalent in today's educational environments. Its immersive and experiential nature promotes increased learner engagement, allows students to gain a deeper understanding of learning materials, while providing an enjoyable and motivating learning experience (AlGerafi et al., 2023; Villagrán-Vizcarra et al., 2023).

In particular, incorporating Augmented Reality technology into classrooms offers several distinct pedagogical benefits and advantages, such as:

1. Transforming traditional classroom spaces into more engaging learning environments by combining physical surroundings with virtual elements (Ji et al., 2025; Zhang & Miao, 2025);
2. Improving the understanding of complex concepts by enabling students to visualise the content and interact with it (Oueida et al., 2023; Erwis et al., 2024; Kaviyaraj & Uma, 2025; Pujiastuti et al., 2024), thereby increasing retention and recall of information.
3. Supporting collaborative learning by promoting social interactions among students within the virtual environment. By combining AR's immersive technology with interactive features such as game-based learning, these collective AR experiences foster collaborative learning, group communication, and team-based learning (Adi et al., 2025; Gardelli & Vosinakis, 2025);
4. Narrowing the gap between formal and informal learning by extending physical classrooms into the real world, thus blurring lines between academic learning and field or experiential learning processes (Lin & Yu, 2023; Hamzah et al., 2025);
5. Promoting creativity, innovation, and critical thinking by exposing students to new modes of expression and problem-solving (Sulistyanto et al., 2024; Lu et al., 2025).

The adoption and use of AR technology in classrooms are not without limitations and challenges. A study conducted by Albishri & Blackmore (2025) identified some barriers and limitations to using AR in education. These include information overload and difficulty visualising abstract concepts in some topics, difficulty using the equipment, network connectivity issues, lack of hardware and software

resources, teacher resistance to integrating AR into the classroom, insufficient training on using AR technology, and excessive time consumption.

However, despite these challenges, research by Pelletier et al. (2022) and Pelletier et al. (2023) has strongly suggested that AR will grow as a highly relevant and developing technology in the education sector, with significant potential to enhance the student learning process. There is a continued need to utilise the immersive nature of these emerging technologies to increase student motivation, foster inquiry-based learning, and support deeper cognitive processing. The disadvantages highlighted by Albishri & Blackmore (2025) further emphasise the need to develop a suitable framework for integrating AR into learning environments in higher education that combines sound pedagogy with technology (Sharma et al., 2025; Li et al., 2025; Lu et al., 2025; Hamzah et al., 2025).

### **2.3 Collaborative Learning**

Collaborative Learning is a learning approach that developed from the Constructivist learning perspective, mainly from the research studies of Piaget (1952) and Vygotsky (1978). Here, learning is optimised when it is conducted both at a cognitive level and supported with social and interactive contexts that emphasise group cooperation rather than competition. In today's education context, collaborative learning is crucial for cultivating 21st-century competencies among learners. A key element of collaborative learning is its social nature, where students exchange ideas and problem-solving activities occur in a social environment.

By learning to collaborate with their peers and engage in group activities, students learn to co-construct new knowledge, build on each other's ideas through group brainstorming, and socially negotiate paths for completing their group's goals. Dillenbourg (1999) also argues that collaborative learning is when a group of people interact to solve or achieve a shared goal. It is a joint activity that requires mutual agreement and decision-making. However, optimal levels of collaboration are not always reached if the group does not actively participate in attaining the common goal, and thus, some guided mechanism needs to be established for it to happen (Nakata et al., 2025).

A study by Paulsen et al. (2024) showed that immersive learning technologies such as AR and VR can have beneficial effects on collaborative activities, and research by Li et al. (2024) showed that students became more engaged in collaborative activities when interacting on a metaverse platform. As such, there remains a growing need to investigate collaborative learning strategies within today's educational sphere, especially amidst emerging immersive technologies that can influence students' interactions and knowledge construction processes.

### **2.4 Pedagogical theories: Gagne's Nine Events of Instruction**

Design education emphasises the need for students to cultivate experiential, creative, critical thinking, and collaborative learning competencies. Educators are thus challenged to identify suitable pedagogical approaches that can assist them in effectively integrating current technologies, such as AR, into the learning environment while fostering these competencies. Constructivist learning theory

by Piaget (1952) posits that learners actively construct their knowledge through experience and interactions. Social Constructivism by Vygotsky (1978) and Dillenbourg (1999) extends Piaget's work by highlighting the social nature of collaboration, which closely aligns with design education. Experiential Learning by Kolb (1984) and Communities of Practice (CoP) by Wenger (1998) underscore the need for students to learn within an authentic and relevant environment where they apply their knowledge through practice and reflection.

However, despite these important affordances, these theories are limited in providing a more structured instructional model that combines cognitive processing and social constructivist approaches. In contrast, Gagne's Nine Events of Instruction (1985) provides a guided instructional model that is better aligned with operationalising immersive environments like AR. Research has shown that Gagne's Nine Events of Instruction has been effective in designing coherent lessons as it aligns instructional design with the conditions of learning (Lin et al., 2024; Li et al., 2025). In particular, Gagne' (1985) posits that there are nine (9) events of instruction that need to be in place to result in effective learning:

1. Gain Attention
2. Inform the learners of the objective
3. Stimulate prior recall
4. Present the content
5. Provide learning guidance
6. Elicit performance
7. Provide feedback
8. Assess performance
9. Enhance retention and transfer

As such, the learning environment in this research combined AR technology with Gagne's (1985) pedagogy, for a soundly designed immersive and interactive learning module that can support the acquisition of higher-order skills as presented in Figure 1.

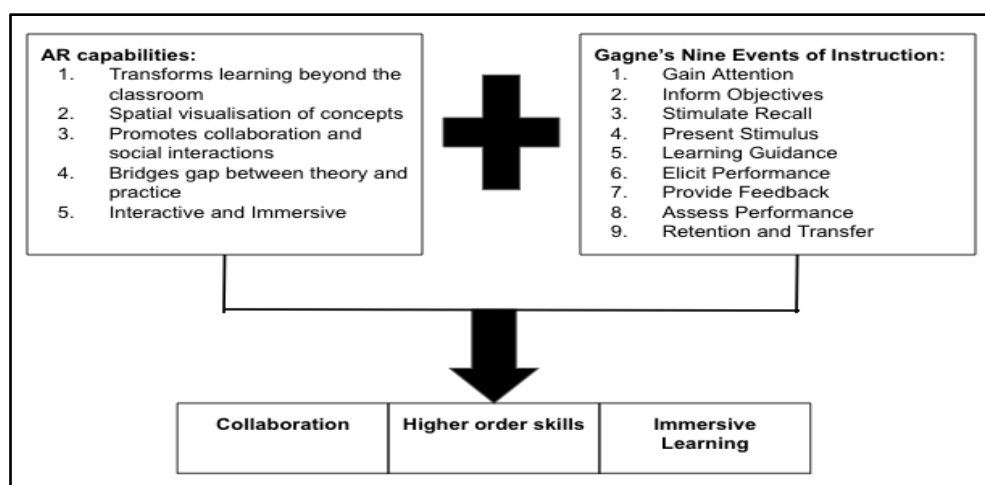


Figure 1: Combining Gagne's Nine Events of Instruction (1985) with AR technology

## 2.5 Using AR in Indonesian Education

In 2022, the Indonesian Ministry of Education, Culture, Research and Technology launched the “Merdeka Belajar” or “Freedom Curriculum” initiative aimed at transforming Indonesian education and aligning it with 21st century academic student learning competencies (Utami & Suswanto, 2022). It was designed to address the predominant education issue in Indonesia of focusing on tests and examinations, and the lack of innovative teaching and learning methods (Hunaepi & Suharta, 2024).

The COVID-19 pandemic accelerated the shift to online learning, which led to the realisation of the need for curricula that provided more opportunities for students to collaborate and engage effectively with each other. This initiative called for educational institutions to develop more flexible and innovative learning environments and shift from teacher-centric teaching towards student-centred learning approaches. It also emphasised the need to integrate Information Communication Technology (ICT) and design curricula that promoted 21st century competencies such as critical thinking, creativity, problem-solving, and collaboration.

Institutions responding to this call have sought to adopt blended and immersive learning methods to enhance student engagement and cultivate 21st century skills. Research conducted by Rizki et al. (2024) on using game-based learning in a Physics class found increased engagement and enjoyment levels among students. Another study by Sulistyanto et al. (2024) found that incorporating AR into a computer networking class in a vocational school improved their critical thinking skills and analytical abilities. Similarly, AR has been successfully used in EFL classes (Nyudak et al., 2024) and STEM education (Prananta et al., 2024). However, despite this governmental policy of support, the adoption of AR in Indonesian design education remains limited, especially at the university level.

While there have been studies using AR in interior design (Maulana et al., 2023), there are few empirical studies on its use in other design disciplines (visual communication, product design, and studio-based courses). In addition, technical infrastructure is also limited due to a lack of resources. Teacher readiness and acceptance levels also vary as universities lack adequate teacher training and sound pedagogical models to support their implementation. This invariably results in a lack of studies investigating AR’s impact on students’ design learning experiences and competencies.

## 3. Methodology

In this study, a collaborative immersive learning environment supported by Augmented Reality (AR) in the School of Creative Industry, Universitas Ciputra, Indonesia, was developed and implemented. A course called Design Project Management was redesigned within an immersive AR-supported learning environment, where students engaged in a virtual, immersive, and cooperative environment while applying the skills and knowledge acquired during their course. Therefore, the learning environment designed for this study encompassed the development of an AR game-based module, called Quinn’s Quest, which was

grounded in Gagne's (1985) Nine Events of Instruction, and integrated into the course as part of a blended learning strategy.

### **3.1 Developing the AR learning environment**

The AR-based learning environment was designed to integrate content, pedagogy, and technology into an immersive learning space where students collaborated to complete their AR tasks. Content from the class was transformed into AR tasks within the module and supported by Gagne's 9 Events of Instruction (1985) as its theoretical framework.

#### *3.1.1 The AR-based module: Quinn's Quest*

An AR-based module was developed with Unity using the content of a design class called "Design Project Management," where students learned how to develop and manage design-based projects. The module was titled "Quinn's Quest" and was based on a scenario involving a student named Quinn on a journey to successfully manage a design project with the assistance of her teammates. The module was created as a game-based application that required students to collaborate in teams and compete against each other to complete the AR tasks, which consisted of 2 levels.

In Level 1, the group's knowledge of the class content was assessed as the group competed within the AR environment to answer several multiple-choice questions. Correct answers allowed the group to collect keys and proceed to the next question. When the group had successfully collected all required keys, they could then advance to the next level. In Level 2, the application of their acquired knowledge from the class was evaluated. Here, groups competed to complete a scenario-based task on managing a design project within a specified time limit. Rule-based features were incorporated into the module in the form of 1) avatars that provided support and motivation to the groups during the application, and 2) feedback that was sent immediately to the groups' emails.

As this application was introduced to students with no prior experience of AR-based tasks or applications, a short briefing and introduction to the module was provided at the beginning of the class. The students were given a demonstration of the application and shown how to navigate the module. Students participated in the AR module using their mobile phones, which were Android-based. Once they were all familiar with the navigation and objectives of the module, they were given 30 minutes to complete the session.

#### *3.1.2 Using Gagne's 9 Events as the theoretical framework*

In this study, Gagne's Nine Events of Instruction (1985) was used to support the instructional design of the AR module. Table 1 presents the mapping of Gagne's (1985) Nine Events to the module design.

**Table 1: Mapping Gagne's 9 Events of Instruction to the application design**

	<b>Gagne's 9 Events of Instruction</b>	<b>The AR learning environment</b>
1.	Gain Attention	Here, the AR module, named " <i>Quinn's Quest</i> ", introduced the lesson using motion graphics such as videos and 3D animations, synchronised with upbeat music.
2.	Inform of Objectives	Students were presented with the lesson's objectives and module expectations through text and audio narration.
3.	Stimulate Recall.	Prior knowledge was recalled through a scenario-based narrative, preparing the students to immerse themselves in the content.
4.	Present Stimulus	The module was made up of 2 levels. Level 1 of the module required students to acquire knowledge from the module through a game-based scenario of acquiring keys for every successful answer given.
5.	Provide Learner Guidance	Rule-based AI (Artificial Intelligence) features were embedded in the module where avatars were created and guided learners in the modules. These avatars would prompt learners and give them motivational feedback to support their learning process throughout the module.
6.	Elicit Performance	Student performance was elicited in 2 levels. In Level 1, students were engaged in knowledge acquisition and construction with the learning material. In contrast, Level 2 required students to implement their knowledge and practice their collaborative and critical thinking skills through a complex scenario-based activity.
7.	Provide Feedback	The module was designed to provide feedback immediately throughout the two levels. This was done via the coaching and support for the AI-driven avatars, where students would be alerted when they scored or made an error in their decision.
8.	Assess Performance	Rule-based AI was also used to assess students' performance throughout the module, where results at Level 1 and 2 were immediately scored and sent to the students based on their performances at each level.
9.	Retention & Transfer	From their performances in Level 2 of the module, students were allowed to retain the knowledge and skills acquired in the module and apply them to the tasks and assignments in the class.

To illustrate this, Figures 2 and 3 show the visuals of the AR module that were mapped to Gagne's (1985) Nine Events of Instruction.

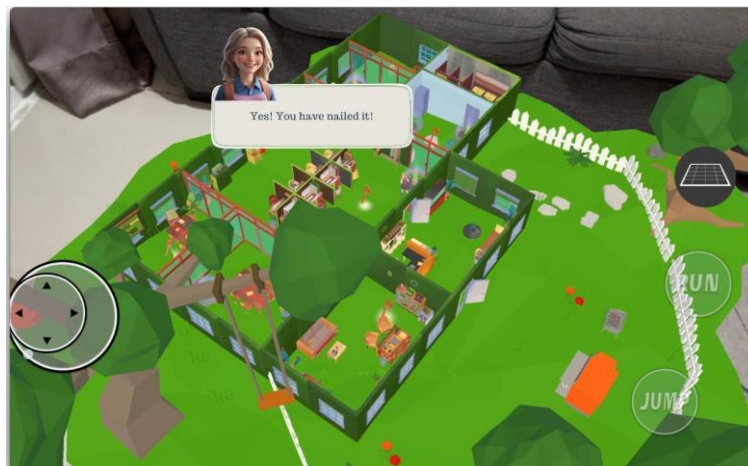


Figure 2: AI-based avatars created to provide guidance to learners in Level 1

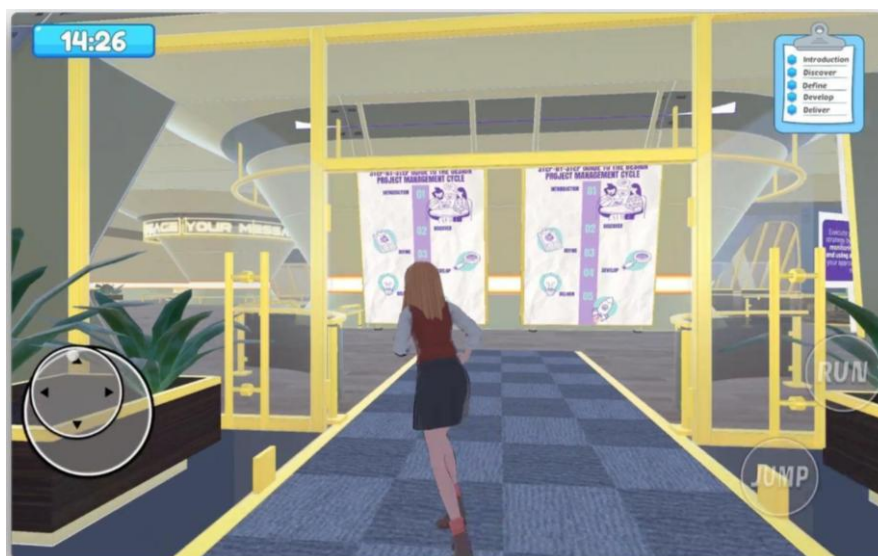


Figure 3: Eliciting performance from learners in Level 2

### 3.2 Data collection and sample

A convergent parallel mixed-method research design was employed in this study. According to Creswell & Creswell (2018), at least two distinct data sources are necessary to achieve triangulation of results. In this study, quantitative data were obtained from a survey questionnaire with items developed from the literature review, and qualitative data were obtained from open-ended questions soliciting students' comments. These data were analysed separately and then compared. Survey data were collected through a 31-item Likert scale survey, open-ended questions with student comments, and triangulated in the analysis.

The survey used a 5-point Likert scale, ranging from 5 = Strongly Agree to 1 = Strongly Disagree. Internal consistency reliability analysis yielded an overall

Cronbach Alpha of 0.985, with individual constructs' Cronbach Alphas presented in Tables 4-8. The survey aimed to assess students' perceptions and attitudes towards the AR game-based module and the overall learning environment. The survey was adapted from Chai et al. (2015), Neo et al. (2024), Gurses et al. (2025), and Davis (1989), and developed to measure students' perceptions on the following constructs:

1. Enjoyment in Learning
2. Use of Augmented Reality (AR) in the learning process
3. Knowledge Construction Experiences
4. Collaboration and Teamwork Experiences
5. Creativity, Critical Thinking and Problem-Solving Experiences

Participants in the study were students from University Ciputra, Indonesia, undergoing the Visual Communication Design Program in the School of Creative Industry and enrolled in a Design Project Management class. Class sizes for this program usually consist of 40-50 students per class, depending on the semester. As such, convenient sampling was employed, and one class of 50 students was selected to participate in the study. Participation was voluntary, and students were provided a consent form to complete at the beginning of the class. In this study, the entire class of 50 students consented to participate and was composed of 38 females and 12 male students.

Out of the 50 students, 49 were Indonesian and 1 was Korean (male). The Quinn's Quest module was given to the students to experience at the 10th week of the semester and complete by the end of the session. In addition to the survey, open-ended questions with student comments were also collected and analysed. These open-ended questions included in the survey consisted of questions such as *"How was your learning experience in this AR blended learning course?"*, *"How do you feel about collaborating with your team in the AR learning environment?"*, *"What did you like most about using AR in your learning?"*, *"How was your motivation level in this immersive AR blended learning environment?"*, and *"Overall, did you enjoy learning in this AR blended learning environment? Please comment."*

These open-ended questions were included in the survey to help strengthen the study by triangulating students' comments with the survey results (Creswell & Creswell, 2018). While the quantitative aspects of the survey provided measurable learning outcomes, these open-ended items allow students to express their experiences more deeply. This further supports the survey findings by providing richer and more meaningful interpretations of the data and a credible understanding of the students' experiences in this AR learning environment.

#### **4. Results and Findings**

The data collected from the survey were analysed using SPSS v29. Reliability analysis was conducted on all 31 survey items and yielded a Cronbach's alpha of 0.985. In addition, individual reliability tests were conducted on each construct as shown in Table 3.

**Table 3: Cronbach Alpha for each construct**

Categories	Mean	Cronbach's Alpha	N
Enjoyment In Learning	3.9640	.890	50
Use of AR in the Learning Process	4.0233	.929	50
Knowledge Construction Experiences	3.9300	.924	50
Collaboration and Teamwork Experience	4.1629	.893	50
Creativity Critical Thinking and Problem Solving Experiences	3.8633	.949	50
<b>Grand Mean for all the categories</b>	<b>3.9887</b>		50
<b>Overall Cronbach's Alpha</b>		<b>.985</b>	

As can be seen in Table 3, the means for all constructs were high and suggest that students were very positive towards these five constructs. Analysis of internal consistency also yielded strong positive values, indicating that the items on the survey were highly reliable.

#### 4.1.1 Descriptive analysis

Descriptive analysis was conducted on the items of the survey, and the results were presented in Tables 4 to 8 along with their corresponding survey items, which include the items' means, standard deviation, and the percentage of students who responded AGREE and STRONGLY AGREE (4 & 5) on the survey scale. In addition, thematic analysis was applied to evaluate student comments from open-ended questions. The responses were coded inductively to identify recurring themes that complemented the quantitative survey results.

**Table 4: Survey Results on Enjoyment in Learning**

Items Cronbach Alpha .890 (n=50)	Mean (M)	SD	% Students (Agree & Strongly Agree)
1. "Collaborating with my peers was enjoyable and fun."	4.32	0.79	80
2. "I am satisfied with my contribution to my group in completing the AR tasks."	4.14	0.81	74
3. "I found this AR environment challenging yet stimulating and fun to do."	4.08	0.92	74
4. "I was motivated to complete the AR tasks."	3.94	1.02	68
5. "Overall, I enjoyed learning in this AR blended environment."	3.9	0.81	70
6. "I am confident in my newly acquired skills from this class."	3.76	1.00	66

**Student comments:**

1. *"The learning experience was engaging and dynamic."*
2. *"I find it engaging since it is like a game and give us a playful experience in learning"*
3. *"I enjoyed the interactive 3D models that brought complex concepts to life."*
4. *"It was a new experience that I haven't done before, so it's exciting to try it out"*
5. *"...the AR experience transformed learning into an active and stimulating endeavor."*

These findings indicate that students derived significant enjoyment from the AR learning environment regarding collaboration, motivation, satisfaction, and contributions. These results suggest that students are more likely to collaborate and work as a team when they experience an enjoyable situation. They are also more likely to feel satisfied with their contributions and more motivated to persist through challenges when they enjoy themselves. The qualitative data support these findings, showing that students appreciated the AR learning environment as game-like, stimulating, and playful. In summary, results for this construct showed that the AR learning environments fostered strong and positive levels of enjoyment where students were highly motivated to collaborate, engage, and contribute to their learning objectives.

**Table 5: Survey Results on Use of AR in the learning process**

Items Cronbach Alpha .929 (n=50)	Mean (M)	SD	% Students (Agree & Strongly Agree)
1. "My class was more enjoyable when my lecturer used AR blended learning tools."	4.26	0.83	84
2. "I find learning in this environment immersive and engaging."	4.16	0.79	80
3. "I like the combination and flexibility of face-to-face classroom and AR blended learning activities."	4.08	0.80	76
4. "I would like similar AR and blended learning classes in my future courses."	4.00	0.88	74
5. "I found the AR blended learning environment to be beneficial to my learning."	3.88	0.87	66
6. "I believe that AR blended learning is an effective way for me to learn."	3.76	0.94	68
<b>Student comments:</b>			
<ol style="list-style-type: none"> <li>1. <i>"The AR component added an interactive layer that made complex concepts easier to understand and more memorable."</i></li> <li>2. <i>"The blend of traditional and augmented learning created a balanced and effective learning environment."</i></li> <li>3. <i>"I like the combination and flexibility of face-to-face classroom and AR blended learning activities."</i></li> <li>4. <i>"What stood out most was the hands-on experience AR provided. Being able to</i></li> </ol>			

*visualize and interact with virtual objects or scenarios made the learning process immersive and practical."*

5. *"Collaborative and more explorative than just sitting in a lecture."*

Overall, results showed strong support for employing AR in the learning process. In particular, students reported enjoyment, engagement, and effectiveness when AR is used in the classroom. The AR environment's immersive nature was enjoyable and interactive. However, it also motivated them to explore further, and the blended learning approach of face-to-face instruction with AR activities provided them with a more meaningful and balanced learning experience. These findings are reinforced by student comments stating that the AR learning environment gave them hands-on experiences that enhanced their attention and retention of information.

**Table 6: Survey Results on Knowledge Construction Experiences**

Items Cronbach Alpha .924 (n=50)	Mean (M)	SD	% Student s (Agree & Strongly Agree)
1. "I felt that the activities gave me authentic and relevant experience."	4.06	0.77	78
2. "The AR learning environment allowed me to acquire new knowledge and skills."	4.00	1.05	68
3. "I am now able to apply what I have learnt to other projects."	3.96	0.73	76
4. "I am able to see the relevance of the AR learning activities to my learning process."	3.86	0.90	60
5. "AR activities provided by the lecturer were useful to improve my classwork."	3.88	0.87	70
6. "The AR environment and activities enhance my understanding of the subject."	3.82	1.02	64
<b>Student comments:</b>			
1. <i>"It bridged the gap between theory and application, making abstract concepts more tangible."</i>			
2. <i>"...we're able to incorporate the real world into the digital world while also learning and recapping our study materials."</i>			
3. <i>"The ability to manipulate virtual objects and see real-world applications in augmented reality was a game-changer."</i>			
4. <i>"...it was a valuable learning experience that enhanced my understanding of the subject matter."</i>			
5. <i>"It was great, I can learn more about the course."</i>			

The findings in Table 6 indicate strong and positive support for knowledge construction and skills development. The majority of students expressed confidence in the new knowledge and abilities acquired and an increased level of

confidence in applying them to their future projects. They reported perceiving the real-world relevance and authenticity in the AR activities. These results are also positively confirmed by the student comments that the AR environment bridged the gap between theory and practice and allowed students to visualise and comprehend complex concepts better. Therefore, AR was integral in promoting meaningful, authentic, and relevant learning of the course content.

**Table 7: Survey Results on Collaboration and Teamwork Experiences**

Items Cronbach Alpha .893 (n=50)	Mean (M)	SD	% Students (Agree & Strongly Agree)
1. "I enjoyed collaborating with my group in the AR environment."	4.32	0.68	88
2. "I enjoyed collaborating with my group to learn about the topics."	4.22	0.71	84
3. "My group members' feedback was important and helpful to me."	4.20	0.83	78
4. "My team and I were able to collaborate well to complete the AR tasks."	4.18	0.77	78
5. "My group and I were able to communicate well to complete the tasks."	4.16	0.77	78
6. "I can learn more when working with my teammates."	4.14	0.93	76
7. "The group was able to achieve our goals in the AR environment."	3.92	0.94	72
<b>Student comments:</b>			
<ol style="list-style-type: none"> <li>1. "... it's also helpful to practice teamwork and collaborations when executing something"</li> <li>2. "The AR environment made collaboration more fun and engaging"</li> <li>3. "It was fun because it's like playing a game with friends"</li> <li>4. "...the collaborative tasks provided a sense of purpose and achievement."</li> <li>5. "That our team can collaborate in a funner way"</li> </ol>			

The results showed that collaboration and teamwork were integral to students' positive learning experiences. It demonstrated that the AR environment fostered effective collaborative learning among students by creating a dynamic, engaging, and stimulating game-based context that positively enhanced peer-to-peer interactions and teamwork. These survey findings were supported by students' comments, indicating that collaboration was more meaningful and authentic with the AR activities. These comments emphasise that the gamified, collaborative nature of the AR environment transformed teamwork from a requirement into a perceived enjoyable and purposeful activity.

**Table 8: Survey Results on Creativity, Critical Thinking and Problem-Solving Experiences**

Items Cronbach Alpha .949 (n=50)	Mean (M)	SD	% Students (Agree & Strongly Agree)
1. "I am able to think more creatively after doing the AR activities."	3.96	0.97	70
2. "Collaborating in the AR environment allowed me to improve my problem-solving skills."	3.94	1.00	62
3. "The AR and web activities allowed me to analyse, synthesise and evaluate information."	3.94	0.89	68
4. "The AR environment allowed me to think critically about this subject."	3.86	1.05	64
5. "I can apply what I learned from this environment to my assignments."	3.84	0.91	60
6. "I am now better able to reflect on my work and how to improve it."	3.64	0.966	56
<b>Student comments:</b>			
<ol style="list-style-type: none"> <li>1. <i>"It fostered a sense of teamwork and creativity as we could brainstorm and problem-solve in a dynamic, 3D environment."</i></li> <li>2. <i>"It encouraged creativity and teamwork by enabling us to manipulate and explore content together in real-time."</i></li> <li>3. <i>"...focused learning with real problem example"</i></li> <li>4. <i>"The shared virtual space allowed for better visualization of ideas and seamless interaction."</i></li> <li>5. <i>"Its colorful visual and challenge by competing with opposite team"</i></li> </ol>			

Findings in Table 8 showed that the AR learning environment effectively promoted meaningful development of students' creativity, critical thinking, and problem-solving skills. By engaging in this environment, students could enhance their problem-solving skills, elevate their creativity and critical thinking, and reflect on and improve their work as a team. Students' comments also supported these results, highlighting their growth as better problem-solvers and creative thinkers through collective brainstorming and communication with each other.

#### 4.1.2 Pearson's correlation coefficient

In addition to the descriptive analyses above, Pearson's correlation coefficient ( $r$ ) was used to evaluate the strength and direction of the linear relationships between two constructs, which range from -1 (perfectly negative correlation) to +1 (perfectly positive correlation). Table 9 presents the findings of Pearson's correlation analysis for each pair of constructs. Overall, results reveal strong positive correlations among all five constructs, significant at the 0.01 level.

Table 9: Pearson's correlation coefficient results (*r*)

Categories	Enjoyment In Learning	Use of AR in the Learning Process	Knowledge Construction Experiences	Collaboration and Teamwork Experience	Creativity Critical thinking and Problem solving
Enjoyment In Learning	1				
Use of AR in the Learning Process	.799**	1			
Knowledge Construction Experiences	.935**	.808**	1		
Collaboration and Teamwork Experience	.862**	.710**	.851**	1	
Creativity Critical Thinking and Problem Solving	.929**	.816**	.948**	.819**	1

\*\* Correlation is significant at the 0.01 level (2-tailed)

As can be seen in Table 9, the Pearson's correlation coefficient analysis showed strong and positive correlations between **Enjoyment in Learning** and **Knowledge Construction Experience**,  $r(48) = .935$ ,  $p = 0.01$ , between **Enjoyment in Learning** and **Creativity, Critical Thinking, and Problem-Solving**,  $r(48) = .929$ ,  $p = 0.01$ . **Enjoyment in Learning** also strongly and positively correlated with **Collaboration and Teamwork Experiences**,  $r(48) = .862$ ,  $p = 0.01$ .

These findings suggest that when students enjoyed their learning process, they were more motivated to focus on the content, construct meaningful knowledge, work as a team, collaborate with their peers, and develop creativity and critical problem-solving abilities. In addition, findings also showed that **Enjoyment in Learning** was positively correlated with **Use of AR in the Learning Process**,  $r(48) = .799$ ,  $p = 0.01$ . This suggests that the more students interact in the AR learning environment, the more they engage in their learning process. This aligns with Gagne's First and Second Instructional events, "*Gaining Attention*" and "*Inform Objectives*," respectively.

This was also evident in the strong and positive correlations between **Use of AR in the Learning Process** with **Knowledge Construction Experience**,  $r(48) = .808$ ,  $p = 0.01$ , with **Collaboration and Teamwork Experience**,  $r(48) = .710$ ,  $p = 0.01$ , and with **Creativity, Critical Thinking, and Problem-Solving**,  $r(48) = .816$ ,  $p = 0.01$ . The presence of AR-related tasks in Quinn's Quest allowed students to improve their knowledge, collaborate effectively with their team, and increase their engagement. These findings support the use of immersive tools such as AR as an effective instructional platform for enhanced student learning outcomes.

This also aligns with Gagne's Third and Fourth Events, "*Stimulate Recall*" and "*Present Stimulus*," respectively.

In addition to strong and positive correlations with **Enjoyment in Learning** and **Use of AR in the Learning Process**, **Knowledge Construction Experiences** also showed strong and positive relationships with **Collaboration and Teamwork Experience**,  $r(48) = .851$ ,  $p = 0.01$ , and with **Creativity, Critical Thinking, and Problem-Solving**,  $r(48) = .948$ ,  $p = 0.01$ . These results suggest that students were able to deepen their understanding of the content when actively collaborating in the AR learning environment, engage in creative problem-solving as a group, and apply their understanding to the AR tasks provided. This finding aligns with Gagne's Sixth and Seventh Instructional Events of "*Eliciting Performance*" and "*Providing Feedback*," respectively.

Similarly, **Collaboration and Teamwork Experience** showed strong and positive correlation with **Enjoyment in Learning**,  $r(48) = .862$ ,  $p = 0.01$ , with **Use of AR in the Learning Process**,  $r(48) = .710$ ,  $p = 0.01$ , with **Knowledge Construction Experiences**,  $r(48) = .851$ ,  $p = 0.01$ , and with **Creativity, Critical Thinking, and Problem-Solving**,  $r(48) = .819$ ,  $p = 0.01$ . These results showed that group interactions were integral to the success of the team within the AR learning environment. The game-like nature and AR activities in Quinn's Quest provided opportunities for students to build social connections and shared decision making. This aligns with Gagne's Fifth, Eighth, and Ninth Instructional events of "*Provide Learner Guidance*," "*Assess Performance*," and "*Retention and Transfer*," respectively.

Moreover, **Creativity, Critical Thinking, and Problem-Solving** had the strongest positive relationships with **Knowledge Construction Experiences**,  $r(48) = .948$ ,  $p = 0.01$ , and with **Enjoyment in Learning**,  $r(48) = .929$ ,  $p = 0.01$ . Following these correlations, there were also positive correlations with **Collaboration and Teamwork Experience**,  $r(48) = .819$ ,  $p = 0.01$ , and with **Use of AR in the Learning Process**,  $r(48) = .816$ ,  $p = 0.01$ .

These findings show that when students enjoy the learning environment, they are more likely to increase their construction of knowledge leading to more critical thinking and problem-solving approaches to learning, with AR-related tasks as the foundation for collaboration and group decision making. This aligns with Gagne's Sixth and Ninth Instructional Events, "*Eliciting Performance*" and "*Retention and Transfer*," respectively.

The results of Pearson's correlation coefficient analysis showed significant positive outcomes on all five constructs of the data. Enjoyment in Learning was shown to be a central factor that enhanced the integration of AR technology in the construction of knowledge, strengthened collaboration and teamwork, and improved creativity, critical thinking, and problem-solving skills. These findings were also closely aligned with Gagne's Nine Events of Instruction and provide strong support for a pedagogically sound AR learning environment.

## 5. Discussion

Guided by the research question, “How does an AR-supported collaborative learning environment impact student learning experiences in design education?”, findings from the study showed strong support for an AR-supported collaborative learning environment. The results of this study culminated in the development of the AR-supported Collaborative Learning Environment (ARCLE) framework, as shown in Figure 4.

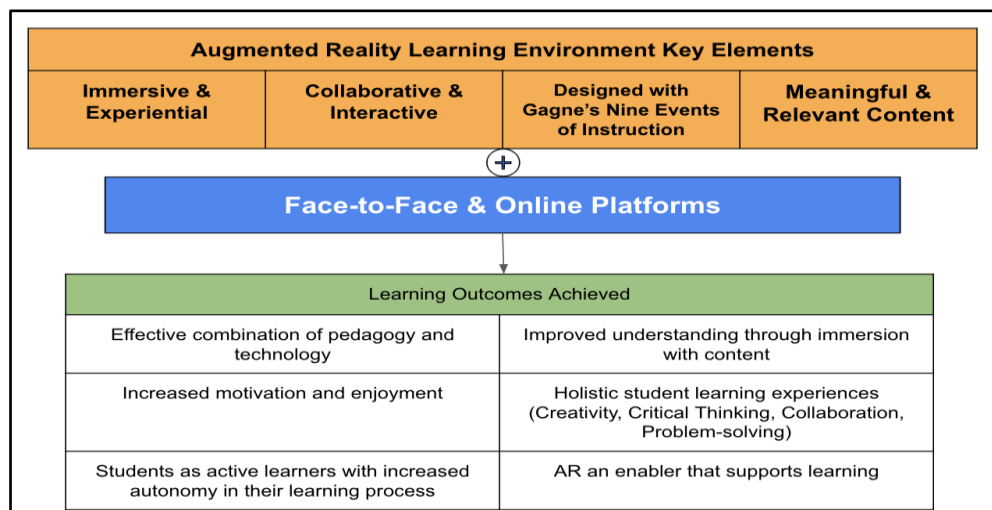


Figure 4: The ARCLE Framework

In the ARCLE framework, the following key learning experiences were achieved:

### 1. Collaboration and Teamwork Experiences

Findings from the study show that students' collaborative and teamwork skills and experiences were significantly improved. Group communication skills were enhanced, peer-to-peer feedback was actively sought after, and clear roles were defined within the AR environment, which led to the achievement and completion of their group goals. The game-based nature of the AR module led to more enjoyable and engaging collaboration among the team members, resulting in an enhanced sense of purpose and achievement. This aligns with findings that AR-supported group collaboration promotes increased teamwork and cooperative efforts (Adi et al., 2025; Gardelli & Vosinakis, 2025).

### 2. Active Learning through Creativity, Critical Thinking and Problem-Solving Experiences

Higher-order learning outcomes such as creativity, critical thinking, and problem-solving skills were successfully integrated into the student learning experience. Students demonstrated greater engagement and involvement in their learning process after completing the AR module. The complex problem-solving in Level 2 of the AR module encouraged deeper analysis and evaluation of information and creative solutions to complete the tasks. This finding aligns with research that AR is effective in promoting deep learning and in enhancing students' creativity, critical thinking, and problem-solving abilities (Sulistyanto et al., 2024; Kaviyaraj & Uma, 2025).

### **3. Increased Understanding and Knowledge Construction Experiences.**

Students demonstrated improved understanding of the subject matter through their experiences with the AR module. Students showed an enhanced level of comprehension of the course content and recognized the authentic and real-world relevance of the theoretical concepts learned in class. This now allows them to apply what they have learned to other situations and future projects outside of this course. This finding concurs with studies by Oueida et al. (2023), Pujiastuti et al. (2024), and Erwis et al. (2025), indicating that AR learning environments support increased knowledge construction and effectively foster enhanced understanding.

### **4. High Levels of Student Motivation and Enjoyment**

The learning environment successfully increased students' motivation and enjoyment in class. The immersive features of the AR module allowed students to interact with and visualize complex concepts that could not have been done otherwise in a traditional classroom. Students reported high levels of motivation and fun with the AR module and overall enjoyment in their learning process. This supports the studies by Kaminska et al. (2023), AlGerafi et al. (2023), and Villagrán-Vizcarra et al. (2023), which show that AR promotes greater motivation among learners (Ji et al., 2025; Zhang & Miao, 2025).

### **5. Gagne (1985) as an Effective Module Design Framework**

Results from the study showed that underpinning the module with Gagne's (1985) Nine Events of Instruction successfully addressed the key learning conditions for students to effectively learn from the module and aligned with research by Lin et al. (2024) and Li et al. (2025).

### **6. Augmented Reality (AR) as an Important Technology Enabler that Supports Learning**

The study demonstrated the use of Augmented Reality (AR) as an effective tool to support the student learning process. Through its immersive nature, AR allowed students in this study to visualise complex concepts, bridge theory and practice, and engage with their learning content, consistent with research by Lin & Yu (2023) and Hamzah et al. (2025). It also provided students with the opportunity to become more active learners, experience more meaningful and authentic contexts, develop creative, critical thinking, and problem-solving skills, and gain more autonomy in their learning process (Sulistyanto et al., 2024; Lu et al., 2025).

#### **5.1. Limitations and Future Research**

This research had some limitations that can be addressed in future research. One of the limitations of this study was the reliance on self-reported data. This has the potential to introduce bias into the findings. In addition, the research was limited to students in the Design Project Management class and, therefore, restricted to a single discipline, mainly students in the Visual Communication program at the University, thus limiting its generalizability. Future research can expand the sample by including project management classes in other departments to investigate the effectiveness of this AR learning environment on the collaborative efforts of students in different disciplines.

Inferential statistical analysis through Pearson's correlation coefficient allowed relationships between constructs to be observed but could not suggest any causal relationships. Future research could incorporate more experimental or quasi-experimental designs to determine causal relationships among these variables. This study only assessed student perceptions of the learning environment and did not consider instructors' teaching experiences. Future research can include instructor-based data and measure their readiness and competencies in managing these hybrid learning environments.

Findings from this study suggest several recommendations. These include redesigning assignments as AR-based activities and aligning them with Gagne's Nine Events of Instruction to ensure that the learning objectives are well integrated. It can also involve implementing more policies for teacher training on the use of immersive technologies, especially for Indonesian educators, and providing instructional design support from universities.

AR-based collaboration and activities can also be designed to promote more open communication within the Indonesian student community, allowing more reserved students to share their ideas and participate anonymously in the virtual environment. Indonesian institutions can also create accessibility policies targeting regions with limited resources through educational outreach programs. Finally, Indonesian educators can develop collaborative AR projects between students and the local community to co-create design solutions that are specific to Indonesia. These limitations, future research, and recommendations would provide a broader perspective on the effectiveness and sustainability of using emerging technologies in Indonesian higher education.

## **6. Conclusion**

This research study investigated the impact of a collaborative Augmented Reality (AR) learning environment on student learning experiences. An AR collaborative module was developed following Gagne's (1985) Nine Events of Instruction and integrated into a design-based course at an Indonesian University. The findings demonstrated that the use of AR, combined with effective pedagogy, can create meaningful and authentic student learning experiences.

In this study, a convergent mixed-method research design was employed. Results show that an AR-supported collaborative learning environment promotes active learning, enhanced understanding of complex concepts, and stronger teamwork and interactions. The pedagogical structure of Gagne's Nine Events of Instruction provided students with the necessary scaffolding that made the learning process more meaningful. This research contributed to the growing evidence that aligning emerging technologies with effective pedagogy can transform and innovate traditional design education and provide essential flexible student-centred learning strategies.

The resulting ARCLE Framework provides educators with a novel and transferable learning model for design education programs in Indonesian higher

education and globally for other developing nations encountering similar challenges of integrating technology meaningfully into large classes to cultivate 21st-century student learning competencies. In particular, the ARCLE Framework has positive implications for increased and targeted teacher training and readiness preparation, academic outreach initiatives for remote regions in Indonesia, and potential for greater confidence in adopting immersive technologies in classrooms.

## 7. Conflict of Interest

There were no conflicts of interest to declare in this paper.

## 8. Acknowledgments

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