

PAPER

Integration of Augmented Reality in Hybrid Learning: Student Perceptions and Acceptance

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ABSTRACT

This study aims to explore students' perceptions and acceptance levels of the use of augmented reality (AR) in hybrid learning, focusing on aspects of usefulness, attitudes, benefits, and perceived limitations. This study is useful in providing insights into the potential of AR as a transformative learning medium that can increase student motivation, understanding, and engagement, while also generating pedagogical recommendations to support more effective hybrid learning implementation. The research method used was a descriptive approach involving 75 students from the Faculty of Engineering, Makassar State University, who had at least four months of experience in using AR. Data were collected through questionnaires and interviews, then analyzed to explore perceptions, attitudes, benefits, and shortcomings of using AR in the context of hybrid learning. The results showed that students had positive perceptions and a high level of acceptance of AR, as indicated by an average acceptance score of 4.12 and a perception score of 3.96. The most significant benefits were an increase in understanding of abstract concepts ($M = 4.32$), an increase in self-directed learning motivation ($M = 4.36$), and more engaging interactivity ($M = 4.41$). However, several shortcomings were also found, such as the potential for excessive dependence that triggers passive learning, technical limitations, concerns about data privacy, and the risk of decreased creativity and originality. The conclusion of this study is that the integration of augmented reality in hybrid learning is worth developing because it has been proven to improve students' understanding, motivation, and collaboration. However, its implementation needs to be supported by pedagogical strategies such as problem-based learning, scaffolding, and critical reflection so that students do not only rely on instant visualization but also continue to hone their creativity, critical thinking, and independent learning.

KEYWORDS

augmented reality (AR), hybrid learning, student perception, technology acceptance, learning motivation

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1 INTRODUCTION

The development of digital technology has driven the transformation of hybrid learning models, in which augmented reality (AR) has become an important innovation that enhances interactivity and immersion in the learning process [1]. Meta-analysis studies show that the application of AR significantly improves learning effectiveness, motivation, and student engagement compared to traditional methods [2], [3]. AR facilitates the visualization of abstract concepts through 3D models and real-time animations, thereby helping students understand complex material in various fields, including science, engineering, and medicine [4], [5]. The use of AR has also been proven effective in improving learning outcomes, knowledge retention, and students' practical and social skills [2], [6]. Challenges such as teacher resistance, technical issues, and accessibility limitations still need to be addressed so that AR implementation can be equitable and inclusive [7], [8].

Hybrid learning models in the digital era still face challenges such as low student engagement, difficulty in visualizing abstract concepts, and cross-location collaboration constraints [9], [10], [11]. AR presents a potential solution by allowing students to interact directly with three-dimensional digital objects, thereby improving their understanding of complex and abstract material [12], [2]. The use of AR has been proven to increase student motivation, engagement, and learning outcomes in a hybrid environment, as well as enrich the collaborative learning experience [13], [14], [15]. AR also supports experience-based learning and social interaction, which are very important in overcoming the limitations of collaboration in hybrid learning [16], [17].

The success of integrating AR into hybrid learning is greatly influenced by students' perceptions and acceptance levels, where positive perceptions can increase active engagement and learning outcomes, while resistant attitudes can hinder learning effectiveness [9], [18]. Research shows that students who have positive perceptions of AR tend to be more motivated, receptive to the material, and actively participate in the hybrid learning process [10], [2]. However, resistance or rejection of AR use, whether due to technical constraints, lack of experience, or low perceived benefits, can reduce learning effectiveness and student engagement [5], [19]. Therefore, further research is needed to explore students' perceptions of AR in hybrid learning, including its benefits, attitudes, and the obstacles they experience, so that the implementation of AR can be more optimal and inclusive [14], [15].

This study aims to explore students' perceptions and acceptance levels of the use of AR in hybrid learning, with a focus on the aspects of usefulness, attitude, benefits, and perceived limitations [9], [20]. Perceptions of the usefulness and ease of use of AR have been proven to be major factors influencing students' attitudes and intentions to accept and use this technology in learning [21], [22]. Students generally show a positive attitude towards AR because this technology is considered capable of increasing motivation, understanding of material, and a more interactive learning experience [18], [2]. However, limitations such as technical constraints, lack of knowledge, and accessibility are still obstacles to the optimal implementation of AR [2], [23]. Therefore, mapping students' perceptions, attitudes, benefits, and perceived limitations is crucial to support the effective integration of AR in hybrid learning [24].

This study uses a descriptive approach involving 75 students from the Faculty of Engineering, Makassar State University (FT UNM), who have had at least four months of experience using AR for hybrid learning. The findings of this study are expected to provide in-depth insights into the potential of AR as a transformative educational tool, as well as generate pedagogical recommendations to support the implementation of more effective and balanced hybrid learning.

2 THEORETICAL FRAMEWORK

2.1 Hybrid learning

The hybrid learning model is a combination of face-to-face (offline) and online learning designed to take advantage of the strengths of both approaches, such as flexibility of time and space, as well as enriching the interaction between students and teachers [25], [2], [6]. Graham (2013) emphasizes that hybrid learning can create flexibility and expand opportunities for interaction, in line with findings that this model gives students the freedom to choose the learning method that suits their needs [27], [28]. However, challenges that often arise in its implementation are low student engagement, suboptimal understanding of abstract concepts, and limited interaction between students in different locations [29], [30]. For this reason, technological innovations such as multimedia integration, artificial intelligence, and digital collaboration are needed to improve the effectiveness of hybrid learning and overcome these obstacles [31], [32].

2.2 Augmented reality in education

Augmented reality is a technology that combines virtual elements with the real world in real time, allowing users to interact with digital objects in their environment [1], [5]. In the context of education, AR plays an important role in helping students understand abstract concepts through interactive and contextual three-dimensional object visualization [2], [7]. Meta-analysis research shows that AR can increase motivation and conceptual understanding and provide a more immersive and meaningful learning experience [2], [33]. AR also encourages active student engagement in the learning process because it provides a contextual, collaborative experience and improves learning outcomes in various fields [15], [34].

2.3 Students' perceptions and acceptance of AR

The success of integrating new technologies into learning, including AR, is highly dependent on students' perceptions and acceptance levels [34], [20]. Within the framework of the technology acceptance model (TAM) developed by Davis (1989), technology acceptance is influenced by two main factors, namely perceived usefulness and perceived ease of use, which have been proven relevant in the context of AR adoption in higher education [34], [35]. Students' positive perceptions of AR, such as ease of use and perceived benefits, can increase engagement, motivation, and learning outcomes [36], [2]. Conversely, students' negative perceptions or resistance to AR can be a barrier to implementation and reduce the effectiveness of learning [37], [20].

2.4 Previous research

A number of studies have examined the effectiveness of AR in hybrid and online learning, where AR has been shown to improve students' conceptual understanding and learning motivation, particularly in science and engineering learning [38], [39].

Meta-analysis studies show that the use of AR significantly improves learning effectiveness, motivation, engagement, and learning outcomes compared to traditional methods, although its impact on collaboration and communication is still limited [39], [40]. Other studies have also found that AR provides a more immersive and interactive learning experience, but there are still obstacles such as device limitations, user readiness, and technical issues such as application stability and adequate device requirements [41], [8]. It still faces similar technical challenges, requiring infrastructure support and training to optimize AR implementation [42].

Augmented reality has great potential in supporting hybrid learning, particularly in increasing student engagement, understanding of abstract concepts, and motivation. However, student perceptions and acceptance are key determinants of its successful implementation. This study expands on the previous AR-TAM research with a more in-depth focus on the use of AR in the context of hybrid learning. Unlike previous studies that emphasized the general acceptance of AR technology, this research explores the impact of AR on the understanding of abstract concepts, learning motivation, and interaction among students at different locations. Additionally, this study also identifies technical constraints such as data privacy issues and limitations of devices, which were less addressed in previous studies. With this approach, the research makes a new contribution to optimizing the use of AR in hybrid learning. Therefore, this study focuses on exploring the perceptions and acceptance levels of students at the Faculty of Engineering, Makassar State University, towards the use of AR in hybrid learning, with an emphasis on the aspects of usefulness, attitude, benefits, and perceived obstacles.

3 METHODOLOGY

This study uses a descriptive research design to investigate students' perceptions and acceptance levels regarding the integration of AR in hybrid learning. This design was chosen because it can provide an in-depth understanding of users' attitudes toward educational technology. Quantitative data were collected through a questionnaire consisting of 25 questions that measure students' perceptions of the use of AR in hybrid learning. The instrument was validated by two experts in educational technology, and reliability testing showed a Cronbach's alpha coefficient of 0.87, indicating good internal consistency.

The sampling was conducted considering the limitations in access to the target population. While this method may introduce potential bias (e.g., lack of representation from certain disciplines or imbalance in technological backgrounds), mitigation efforts were made by ensuring participant diversity based on: 1) Field of study (science, humanities, and vocational); 2) Previous experience with AR; and 3) Gender. Students from universities with adequate hybrid learning infrastructure were selected as respondents, given that the implementation of AR requires sufficient technical support. The findings of this study may not be generalizable to institutions with significant digital gaps or non-hybrid learning models.

4 FINDINGS AND DISCUSSION

A total of 75 FT UNM students participated in this survey. The researcher used *convenience sampling* to collect data from participants who were available during the study. The participants were first-year to final-year students (aged 20–23 years)

from various departments in the Faculty of Engineering, all of whom had at least four months' experience in using AR for hybrid learning. In practice, students utilized mobile devices in the classroom through AR integration to enhance educational interaction, visualization of complex material, and collaborative simulation in a hybrid environment. This study aimed to explore their perceptions and level of acceptance of AR technology as a tool to support academic achievement.

Table 1. Respondent characteristics based on gender and year of study in the research on augmented reality integration in hybrid learning

Variables and Modalities	Frequency	Percentage
Gender		
– Male	43	57.3
– Female	32	42.7
Year of Study		
– Class of 2024	36	48.0
– Class of 2023	21	28.0
– Class of 2022	12	16.0
– Class of 2021	6	8.0

Based on the results of a survey involving 75 students from the Faculty of Engineering, Makassar State University, the characteristics of the respondents can be seen from the aspects of gender and year of study (see Table 1). In terms of gender, the number of male respondents was higher than female respondents, namely, 43 people, or 57.3%, while female respondents numbered 32 people, or 42.7%. This shows that the majority of respondents in this study were male students. Furthermore, when viewed from the year of study, the respondents were dominated by students from the class of 2024, with 36 people or 48.0%. This was followed by 21 respondents (28.0%) from the 2023 cohort, 12 respondents (16.0%) from the 2022 cohort, and the smallest number of respondents (6 respondents or 8.0%) from the 2021 cohort. These findings show that most respondents were from the most recent cohort, so the perceptions obtained in this study largely reflect the views of new students on the use of Augmented Reality (AR) in hybrid learning.

4.1 The findings from the questionnaire

The integration of AR in hybrid learning has emerged as an innovative response to overcome profound challenges in educational models that combine face-to-face and online elements. This is reinforced by [43]: the visualization of abstract concepts and cross-location interactions, because AR is capable of superimposing digital information onto the real world, thereby bridging the physical-digital gap. Hybrid learning often faces obstacles in maintaining student engagement, presenting visualizations of abstract concepts, and facilitating smooth interaction between learners in different locations. AR, with its ability to superimpose digital information onto the real world, offers a potential solution by bridging the gap between the physical and digital worlds. The same finding by [39] is that AR also offers a potential solution with interactive 3D visualizations that improve understanding

and knowledge retention. Students' perceptions of this technology integration are generally very positive; they view AR as a tool that can transform the learning experience by making complex concepts more tangible and easier to understand through interactive 3D visualizations, thereby improving knowledge retention and learning motivation. Furthermore, AR is perceived to facilitate better collaboration by providing shared digital objects that can be collectively manipulated by students, both those in the classroom and those participating online.

Table 2. Integration of augmented reality in hybrid learning: Student perceptions and acceptance

Variable	N	Min	Max	Mean (M)	SD
Students' perceptions of Augmented Reality integration	75	2.0	5.0	3.96	0.72
Acceptance of Augmented Reality technology in hybrid learning	75	2.0	5.0	4.12	0.65
AR suitability for learning needs	75	1.0	5.0	3.78	0.81

Based on data (refer to Table 2) collected from 75 students, the research findings regarding the perception and acceptance of AR in the context of hybrid learning are presented in Table 2. Overall, the results show a positive response from students towards the integration of AR technology. The AR technology acceptance variable recorded the highest average score ($mean = 4.12$; $SD = 0.65$), indicating that, in general, students accept and have a positive attitude towards the use of AR in hybrid learning. The score for the variable of student perception of AR integration was also very high ($mean = 3.96$; $SD = 0.72$), indicating that the majority of students view this technology as useful and effective. However, the variable of AR suitability for learning needs obtained a slightly lower average score ($mean = 3.78$; $SD = 0.81$). Although still in the positive category, this indicates greater diversity of views among students (marked by a higher standard deviation) regarding the extent to which AR meets their specific learning needs.

Table 3. Students' views on the use of augmented reality in hybrid learning as a tool for visualizing complex concepts

No.	Statement	N	Min	Max	Mean (M)	SD
1	I feel that the use of Augmented Reality is simple and practical in hybrid learning.	75	1	5	4.18	0.81
2	I believe Augmented Reality can help me understand complex concepts more effectively.	75	1	5	4.04	0.85
3	Learning to use Augmented Reality in hybrid learning is enjoyable.	75	1	5	3.92	0.94
4	I find it easy to understand the subject matter when it is visualised through Augmented Reality.	75	1	5	3.97	0.88
5	I think Augmented Reality helps me save time in understanding difficult concepts.	75	1	5	3.78	0.98
6	I would like to use Augmented Reality to visualise learning materials in the future.	75	1	5	3.89	1.01

The research results indicate that students have a positive perception of the use of AR in hybrid learning (refer to Table 3), in line with the meta-analysis by Garzón and Acevedo (2019) that AR increases motivation and understanding of abstract concepts. The aspects of simplicity and practicality received the highest scores ($M = 4.18$), in accordance with the TAM framework (Davis, 1989). AR is also effective in understanding complex concepts ($M = 4.04$) and visual material ($M = 3.97$), supporting the findings of Lin and Yu (2023). The lowest time efficiency ($M = 3.78$) was influenced by technical limitations (Alzahrani, 2020). The desire to use AR in the future ($M = 3.89$; $SD = 1.01$) indicates sustainable prospects despite varying student experiences.

Table 4. Students' perceived attitudes toward the use of augmented reality in hybrid learning

No.	Statement	N	Min	Max	Mean (M)	SD
1	I use Augmented Reality to increase my interest and motivation in hybrid learning.	75	1	5	3.68	1.10
2	I use Augmented Reality to enhance my ability to understand concepts visually.	75	1	5	4.04	0.99
3	I use Augmented Reality to enrich my ideas and understanding in hybrid learning.	75	1	5	3.92	0.75
4	I feel that Augmented Reality helps me understand the subject matter and its context more deeply.	75	1	5	3.97	0.92

Augmented reality in hybrid learning (see Table 4). The mean values ranged from 3.68 to 4.04 with SDs of 0.75–1.10, indicating positive perceptions. In terms of motivation and interest in learning, the average of 3.68 ($SD = 1.10$) shows the contribution of AR despite the high variation in responses. Visual concept understanding obtained the highest average of 4.04 ($SD = 0.99$), confirming the effectiveness of AR. The aspect of enriching ideas scored 3.92 ($SD = 0.75$) with consistent perceptions. In-depth understanding reached 3.97 ($SD = 0.92$). Overall, AR was proven to be effective in increasing motivation, visual understanding, idea enrichment, and material deepening in hybrid learning.

Table 5. Perceived benefits of augmented reality use in hybrid learning by students

No.	Statement	Mean	SD	Min	Max	Variance
1	The use of AR helps me understand abstract concepts more easily.	4.32	0.62	3	5	0.39
2	AR makes the learning process more engaging and interactive.	4.41	0.56	3	5	0.31
3	With AR, I understand difficult material more quickly.	4.28	0.67	3	5	0.45
4	AR helps me remember the lesson material longer.	4.20	0.71	3	5	0.50
5	AR increases my motivation to study independently.	4.36	0.64	3	5	0.41
6	I feel that hybrid learning with AR is more effective than traditional methods.	4.33	0.60	3	5	0.36

Based on Table 5, all AR benefit indicators obtained high averages (4.20–4.41) with low SDs (0.56–0.71), indicating positive consensus among students. Understanding of abstract concepts achieved a mean of 4.32 (SD = 0.62; variance 0.39), confirming the effectiveness of AR. Interactivity and learning appeal obtained the highest score (mean = 4.41; SD = 0.56), increasing student engagement. Understanding of difficult material scored 4.28 (SD = 0.67), while material recall scored 4.20 (SD = 0.71). Self-directed learning motivation reached 4.36 (SD = 0.64), and effectiveness compared to traditional methods was 4.33 (SD = 0.60; variance 0.36). The findings confirm that AR enriches understanding, retention, independence, and hybrid learning experiences.

Table 6. Students' views on the use of augmented reality in hybrid learning regarding perceived shortcomings

No.	Statement	N	Min	Max	Mean	Standard Deviation (SD)	Variance
1	I think Augmented Reality may have data security or user privacy issues.	75	1	5	4.05	0.95	0.90
2	I feel that AR-based learning materials sometimes present inaccurate or outdated content.	75	1	5	3.88	0.98	0.96
3	I think Augmented Reality does not help in understanding technical concepts.	75	1	5	2.75	1.20	1.44

Table 6 shows that although students rated AR positively, there were several weaknesses. The average score ranges from 2.75 to 4.05 with an SD of 0.95 to 1.20, indicating differences in perception. The main concern relates to data security and privacy (mean = 4.05; SD = 0.95; variance = 0.90), which is considered an important issue even though a small minority disagree. Inaccurate or outdated content (mean = 3.88; SD = 0.98) indicates the need for material updates. Support for technical understanding received the lowest score (mean = 2.75; SD = 1.20), with significant differences in opinion. The findings confirm that AR is useful, but challenges such as privacy, content accuracy, and technical understanding must be anticipated.

4.2 Interview results

Perceived usefulness. Based on the interview results, 68 out of 75 participants (90.7%) agreed that the use of AR is useful in hybrid learning. While the quantitative data show that most students agree on the benefits of AR, interviews offer more nuanced perspectives by highlighting technical limitations and potential risks such as excessive reliance on digital simulations. These complementary findings suggest that AR's overall effectiveness in hybrid environments is shaped by both measurable outcomes and deeper contextual experiences.

“For brainstorming activities in hybrid group projects, I believe augmented reality is very helpful. The ideas we discussed face-to-face and virtually, AR can display 3D simulations that enrich perspectives and spark creative thinking.” (Student 4, interview quote).

The research results show that 90.7% of participants (68 out of 75) have a positive view of the use of AR in hybrid learning. This positive view confirms the potential of AR in enriching the learning experience through interactive visualization. However, to understand the impact of AR more deeply, let us analyze these findings in the context of existing literature and emerging technical issues.

Although most participants felt the benefits of AR in exploring concepts and creativity in discussions, the research results also indicated the same as [44] that time efficiency was the least felt benefit by students. Explicitly, the acknowledgement that AR does not significantly accelerate the learning process raises questions. Why do students feel this way? In interviews, several participants mentioned that technical problems often arise when using AR, such as software difficulties, hardware limitations, or internet connection issues.

These issues create barriers that reduce the effectiveness of AR in learning, diverting students' focus from learning to solving technical problems. This is in line with previous research by [45] and [46] that technical issues such as device limitations, software problems, and unstable internet connections create significant barriers that reduce the effectiveness of AR in learning, as students focus more on solving technical problems than on the learning process itself.

These results highlight the gap between the potential of AR and the reality of user experience, which is also reinforced by [40], where technical barriers can divert students' focus from learning to solving technical problems, thereby reducing the effectiveness of AR in supporting constructivist-based learning.

Piaget and Vygotsky's constructivist theory emphasizes the importance of real experiences and social interaction in building conceptual understanding, as conveyed by [47]. AR ideally functions as a bridge between the real world and abstract concepts, but technical constraints can hinder critical thinking and meaningful collaboration. Therefore, adequate training for students and teaching staff is essential so that they can maximize the benefits of AR and reduce barriers to use, as cited in [48] and [40]. Investment in technology and infrastructure that supports AR-based learning is necessary to ensure that AR can be an efficient and effective tool in achieving 21st-century learning goals, as reinforced by [49] and [50].

Perceived attitudes. Based on the interview results, 60 out of 75 participants (80%) expressed positive views on the use of AR in hybrid learning. The majority of participants assessed that AR is capable of visualizing abstract concepts and helping to overcome mental blocks. They also believe that AR can support the preparation of learning materials more efficiently and save time in the process of exploring concepts.

"I have a positive attitude towards AR in hybrid group discussions. This technology deepens conceptual understanding, provides new visual perspectives, and helps overcome mental blocks when analyzing complex topics." (Student 1, interview excerpt)

The findings show that the majority of participants considered the integration of AR in hybrid learning to be effective in clarifying abstract concepts. This is in line with the findings [51], [52], [53], [54], [55], and [56] that AR can improve cognitive understanding through concrete and interactive visualization. Furthermore, AR supports learning efficiency because 3D visualization accelerates concept exploration before discussion, as studies [51] and [57] also show that AR accelerates understanding and increases learning motivation. Student interviews confirm that AR triggers creativity and overcomes mental blocks, thus functioning as a trigger for critical discussion, which is also reinforced by [58], [59]. Thus, in line with [53] and [57], AR is relevant as a 21st-century learning strategy that emphasizes creativity, collaboration, and higher-order thinking skills.

Student 6 expressed concern that AR could potentially inhibit creativity. He argued that over-reliance on AR visualizations could reduce independent exploration skills. The solution, he suggested, was for students to brainstorm first, then use AR as a reference to enrich the visual context.

"I disagree with using AR directly in brainstorming. I prefer to develop ideas independently rather than relying on AR simulations. That way, my imagination is more stimulated." (Student 6, interview excerpt)

Two participants were negative, worrying that AR causes laziness and a decline in the originality of ideas. Relying on this tool is feared to trigger a passive mindset in problem-solving.

“I am skeptical about AR-based discussions. Many students use it without processing their own knowledge, even just to get quick marks in project assignments.” (Student 7, interview excerpt)

Two other students were neutral because the AR trend has both advantages and disadvantages. They emphasized the importance of using AR wisely to maximize its benefits.

“After using AR several times, my attitude is neutral. This technology offers many visualizations of ideas, but not all of them are relevant. So, I combine my personal understanding with the help of AR.” (Student 10, interview excerpt)

Perceived benefits. Based on the interview results, 60 out of 75 participants (80%) highly rated AR ability to instantly visualize complex concepts. Additionally, they highlighted their satisfaction with AR’s speed in displaying interactive simulations that enrich understanding.

“The main advantage of AR in hybrid discussions is real-time visualization and multi-dimensional exposure that broadens learning perspectives.” (Student 8, interview quote)

Based on the interview results, 60 out of 75 participants (80%) highly rated AR ability to instantly visualize complex concepts. Participants also expressed satisfaction with the speed of AR in displaying interactive simulations that enrich understanding. This was confirmed by a quote from one of the students: *“The main advantage of AR in hybrid discussions is real-time visualization and multidimensional exposure that broadens learning perspectives.”* (Student 8).

A total of 22 out of 75 participants (29.3%) acknowledged that AR helped them explore the material before the hybrid session, with three main benefits: (1) time savings, as it shortened learning preparation, in line with statement [60]; (2) conceptual reinforcement through 3D visualization of technical terms and abstract principles, as stated in [61]; and (3) [62] also states that collaboration readiness is a form of “cognitive warm-up.” These findings confirm the effectiveness of AR in visualizing abstract concepts in real time and accelerating understanding. AR acts as cognitive scaffolding, reinforcing basic understanding while promoting 21st-century skills such as critical thinking, creativity, and collaboration, which is in line with the findings [60].

Perceived shortcomings. Based on the responses of **75 participants**, most highlighted the risk of over-reliance as the main problem with using AR in hybrid learning. Of all respondents, seven out of ten students stated that the ease of AR visualization could potentially make them overly reliant on digital simulations as their main source of understanding. *“The ease of AR visualization makes students tend to rely on digital simulations as their primary source of understanding.”* (Student 9, interview quote)

Of the 75 participants, most highlighted that one of the main weaknesses of AR in hybrid learning is the risk of over-reliance. Interestingly, seven out of ten students admitted that the ease of visualization offered by AR made them overly reliant on digital simulations. This creates a phenomenon called “cognitive offloading,” where they feel less need to think independently, a view that is also reinforced by research [63]. On the other hand, although AR can increase motivation and engagement in learning through immersive and interactive experiences—as stated by [2]—[63] reminds us that there is a negative potential, namely the weakening of critical skills and self-regulation abilities. Therefore, it is important to combine AR with a scaffolding approach, as done by [64], and to include reflection, discussion, and

problem-based learning. In this way, students can build conceptual understanding independently and more deeply.

The ease of access to AR simulations is considered to reduce independent exploration efforts. Participants do not need to spend time imagining concepts abstractly because AR provides instant representations.

“Excessive use of AR can make students passive in exploring ideas.” (Student 6, interview quote)

These findings indicate that the use of augmented reality (AR) has the potential to lead to *passive learning*, where students do not need to make an effort to imagine abstract concepts. This has an impact on the decline of higher-level cognitive activities. Research by [65] and [66] supports this view, while cognitive load theory also confirms that when information is too easy to process, mental engagement tends to decrease, as explained by [67]. In this context, the risk of technological dependence and reduced metacognitive skills due to excessive use of AR is a serious concern. [68] and [66] mention that students may become less skilled in self-regulation and critical reflection. Therefore, although AR has been proven effective as a visual aid in learning, it is important to balance its use with active learning strategies such as *problem-based learning* and *inquiry-based learning*. This approach can stimulate critical reflection and independent learning, as proposed by [65] and [69]. Through the combination of these methods, students can become more involved in the learning process and develop deeper thinking skills.

Some participants (three individuals) acknowledged that AR has the potential to limit original thinking. Instant visualization can hinder the process of independent idea construction, particularly in creative problem solving.

“AR reduces the space for me to develop initial concepts imaginatively before they are visualized.” (Student 6, interview quote)

This finding is in line with the concept of *cognitive offloading*, where technologies such as AR provide conveniences that can shift thinking activities from the internal to the external realm. This can reduce the cognitive stimulation needed for creative thinking, as expressed by [70] and [71]. Although AR can support conceptual understanding, excessive use can hinder the *divergent thinking* process, which is an important foundation for creative problem-solving. Research by [68] and [72] emphasizes this risk, showing that unbalanced use of AR can reduce students' ability to generate new ideas.

The academic implications of these findings highlight the importance of balanced AR-based learning design, where the provision of instant representations needs to be accompanied by activities that encourage originality. Activities such as brainstorming, open idea exploration, or *design thinking* are essential for enhancing student creativity. Thus, the integration of AR in hybrid learning must go beyond a focus on ease of visualization. It is also important to encourage the development of creative and original thinking skills, which are essential in the context of 21st-century education, as stated by [73]. With this balanced approach, students can optimally utilize technology without losing their essential creative thinking abilities.

5 CONCLUSION

This study shows that AR has great potential in improving the quality of hybrid learning, particularly in terms of understanding abstract concepts, learning motivation, and student engagement. A survey of 75 students from the Faculty of Engineering at UNM showed that the majority of respondents had a positive perception and

high level of acceptance of AR use. They considered AR to be simple, practical, and effective in helping them understand complex concepts through interactive visualization. AR has also been proven to provide significant benefits, such as improving material retention, enriching collaboration, and encouraging independent learning. However, this study also found several shortcomings and challenges, including the potential for excessive dependence (passive learning), the risk of decreased creativity and originality, technical problems, and concerns about content accuracy and data privacy. Overall, the integration of AR in hybrid learning is worth further development, provided that it is accompanied by appropriate pedagogical strategies, such as problem-based learning, critical reflection, and scaffolding, so that students do not only rely on instant visualization but also continue to hone their creativity, critical thinking, and independent learning skills. Future research should consider a larger and more diverse sample, including students from various institutions with differing AR infrastructure. It would also be beneficial to explore the long-term effects of AR on student motivation and critical thinking skills in hybrid learning environments.

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