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Alternate Reality Game and Augmented Reality: Do They Complement in Promoting Students' Self-Efficacy for Science Learning

Tatik Indayati, Wulan Rahayu, & Hanah Karinsa*

Fakultas Tarbiyah dan Keguruan, UIN Sunan Ampel Surabaya, Indonesia

Abstract: Self Efficacy (SE) plays an important role in improving students' academic achievement in science education. This study explores the integration of Alternate Reality Games (ARG) and Augmented Reality (AR) technology to improve students' SE during science learning. Employing a Systematic Literature Review (SLR) guided by the PRISMA framework, this research analyzes 41 studies published between 2020 and 2024. The PICO methodology was applied: Participants (students in science education), Intervention (ARG and AR implementation), Comparison (traditional teaching methods), and Outcome (improved SE). ARG immerses students in interactive narratives and problem-solving scenarios, fostering critical thinking and resilience, while AR enhances conceptual understanding through immersive and visual simulations of scientific phenomena. The combined ARG and AR app offers a comprehensive learning experience, facilitating deeper engagement and increased confidence in academic abilities. However, challenges such as technological infrastructure and educator readiness remain significant barriers to implementation in developing countries. These findings highlight the complementary roles of ARG and AR in advancing science education, demonstrating their potential to create inclusive and engaging learning environments. However, AR plays a more significant role than ARG, particularly in enhancing students' conceptual understanding and active participation, which directly impacts their self-efficacy.

Keywords: self efficacy, alternate reality games, augmented reality.

▪ INTRODUCTION

The results of the research revealed that students' failure in achieving academic achievement optimally in science was caused by the lack of their SE when they learned science (Chan & Lay, 2021; Hafizan et al, 2024 & Hasanah et al, 2021). Self-efficacy is students' belief that they can achieve their goal based on their ability and their existing condition (Bandura, 2006). If student has high SE, she or he can improve their metacognitive skill, such as: planning, monitoring and evaluating the situation that the student faced (Karaoğlan-Yılmaz et al, 2019). SE is an essential factor which influences the level of effort expended and student persistence in learning (Mornar et al, 2022, Zimmerman, 2000). A meta-analysis study done by Richardson et al (2012) revealed that SE is the most effective predictor of student's achievement in science of all other constructs, such as: intrinsic motivation, extrinsic motivation, and learning goals.

There are two types of SE based on science leaning context (Yang et al, 2021): (i) SE of Science Learning Ability refers to student's self-confidence if the student has ability to finish his or her study successfully, to get good score and to avoid academic failure. This SE leads to student's confidence in learning science. (ii) SE of Science Learning Behavior relates to student's self-confidence regarding his or her ability in adopting certain learning method to achieve learning goals. This SE is more inclined to self-confidence regarding the application of effective learning method. Therefore, several methods to increase student's SE in science context had been done by several researchers

Tatik Indayati
*Email: indayatitatik@uinsa.ac.id

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(Xinyang Hu et al (2022). One of the methods had been done by Han et al (2021) by integration Science subject with Technology, Engineering, and Mathematics (STEM). This method encouraged students to act as scientists in problem solving and it showed that it was able to strengthen students' SE in science.

Another study showed that active learning and setting students' independent learning have been proven to be able to increase students' SE in finishing science assignments (Bogdan et al, 2024; Wang, 2023). Giving bigger responsibility of learning process to students can encourage students to increase their SE through learning experience which is more independent and reflective. By this method, students felt secure to experiment and to ask, so it has an impact of increasing SE significantly and learning process became more effective dan useful. One of learning approaches that has potential to increase students' SE is ARG approach. ARG is an approach which combines real and digital element in the form of interactive narrative media which the players engage in puzzle, story and real-life activity (Sofianidis et al, 2024). In ARG, narrative is built in layers by utilizing digital technology, such as: website, email, social media and physical elements (geographical location, newspaper and book) (Tulloch et al, 2021). These elements make the game set in fictional world feel real. Moreover, ARG encourages students to play an active role to find instructions in completing tasks and challenges on digital platform. It can hone student's cognitive skill and emotional abilities (Elsom et al., 2023). Result of study by Shchory et al. (2024) showed that ARG could create interactive learning environment, decrease anxiety level and increase student's SE.

Apart of ARG utilizing digital technology, there are some approaches which are in line with advances in digital technology, Artificial Intelligence (AI), Internet of Things (IoT), and Cloud Computing namely AR (Dargan et al, 2023). AR is an approach which is utilizing technology and combining real world and digital element which virtual objects were projected into the physical environment via a device, such as: smartphone, tablet or special headset. Report from International Data Corporation (IDC) predicted that AR market will achieve more than $50 billion than 2026 (Golov et al, 2023). The rapid development of AR shows the big potential in the future especially in science education field (Masneri et al, 2024). ARG and AR have their own unique characteristic to create learning science experience which is deeper and interactive. By combining ARG and AR, learning became more immersive where interactive narrative brought by ARG was enriched by digital elements that were visible directly in the real-world through AR. This combination did not only encourage students' involvement in solving science complex task through ARG, but it also involved students to interact directly through AR to increase SE.

There have been many studies which tried to explore ARG and AR contribution in increasing student's SE in learning science, but comprehensive study which is focused on both contributions simultaneously in self-efficacy is not still widely done. For instance, a study done by Angelos Sofianidis was still focused on AR and ARG implementation in education context especially in increasing learning experience and student learning outcomes (Sofianidis et al, 2024). A study done by Nguyen (2023) also reviewed several literatures to highlight effectiveness, challenges and opportunities which was offered by the combination of AR and ARG in STEM education context. The main focus of the research was about how the integration of both technologies could enhance engagement, motivation and student learning outcomes in STEM education.

Based on the previous descriptions, there is a research gap related to AR and ARG in increasing student's self-efficacy in learning science. Therefore, this research focused on how ARG and AR contribution could increase students' SE and focused on implementation challenges, such as: insufficient technology infrastructure and teacher training need, especially in developing countries. This research is expected to be able to give specific understanding toward learning approach and student challenges in learning science and provide relevant solution to overcome the challenges in education context in developing countries.

By doing SLR will be able to capture findings that have been existed and to give more comprehensive analysis related to ARG and AR in increasing student's SE in learning science effectively. The statement revealed that even though there have been many studies which have been conducted in recent years, but there is still a need to look at research trends related to ARG and AR in increasing students' self-efficacy in learning science. It means that it requires research which is more structured and comprehensive to see if ARG and AR simultaneously can provide contribution in increasing students' self-efficacy or both contributions partially. Findings in this research is expected capable to give contribution substantially in increasing students' SE by presenting learning environment which is more inclusive and interesting through the implementation of AR and ARG approach which is proven to be effective in supporting learning process.

▪ METHOD

This research was descriptive qualitative study which used Systematic Literature Review (SLR) to identify, to analyze and to synthesize literature systematically. SLR is data preparation method systematically (Baktayan et al, 2024) which is to analyze and to summarize relevant researches as basic problem solving. This technique combines several sources including article journal, book and website to develop solid theoretical basis (Ramsurun et al, 2024). Literature used in this research included journal and article journal which was focused on the implementation of ARG and AR in increasing students' self-efficacy.

This research applied Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) method which was designed to increase transparency and comprehensiveness in systematic review report and meta-analysis (Ranjbar et al,. 2024; Cevikbas et al,. 2024). This research was to investigate the potential of increasing students' self-efficacy through the implementation of ARG and AR approach. Literature review was done by searching related article journal about ARG and AR which were taken by several reputable databases, such as: Scopus, Springer, Crossref, and Eric which used a tool called "Publish or Perish" to ensure the completeness and the source relevance.

Search Strategy

PRISMA methodology ensured that every selected source fulfilled the relevance and validity criteria for systematic analysis. Article selection process was customized to specified guidelines. Article was searched by keywords drawn in Table 1.

Table 1 showed that keywords used to search relevant articles were ARG and AR. The focus determined in this literature led to ARG and AR approach in increasing students' self-efficacy in learning science. There were 2.652 literatures from four databases which were relevant with the keywords. Then, those articles were filtered by several stages. This process included the first filter using software. Covidence was to

Table 1. Keywords used to search relevant articles

Database	Keywords
Crossref	Alternate reality game and augmented reality in science education
Springer	Alternate reality game and augmented reality in science education
Scopus	Augmented Reality Science Learning
Eric	Augmented Reality Science Learning Alternate Reality Game and Augmented Reality

delete duplicate and to identify articles based on inclusion-exclusion. After articles were identified as meet the requirements. The next step was downloading full-text and separating inclusion and exclusion articles. This phase, qualified articles must capable to map answers of research questions. The following was article search process by PRISMA:

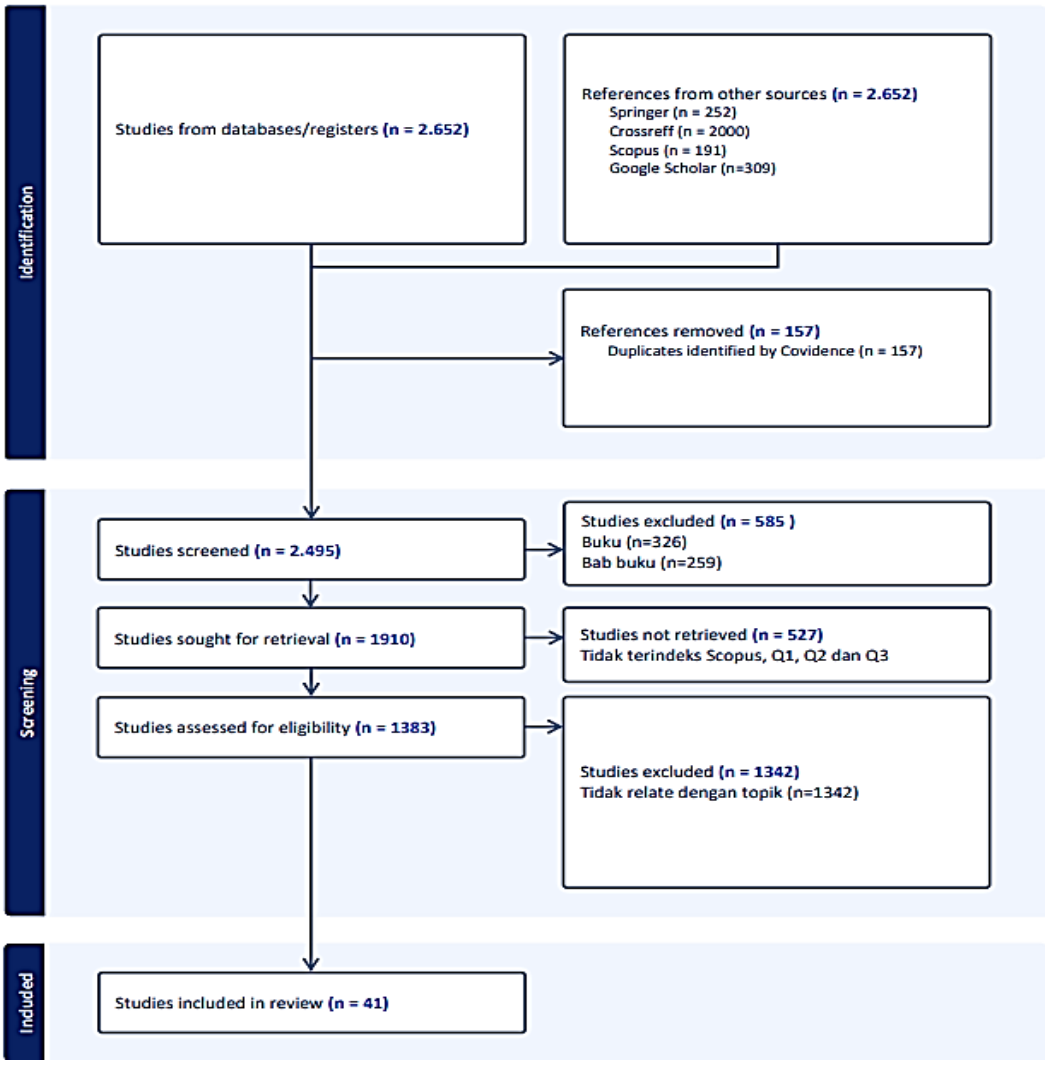

Figure 1. Article search process by PRISMA

The PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) flow process consists of four main stages: identification, screening, eligibility and inclusion. In the identification stage, data sources such as databases and other

references are collected. Scopus, Springer, Crossref and Eric were the databases used for this systematic literature review. In this document, data was obtained from various sources such as Springer (252), Crossref (2000), Scopus (191) and Google Scholar (309), with a total of 2.652 references identified. At this stage, duplicate references were removed using tools such as Cobidence, which resulted in the removal of 157 data.

The next stage was screening. Literature. Literature results from Scopus, Springer, Crossref and Eric databases were screened through Covidence software to separate duplicate articles. Next was tile and abstract filtering process. Titles were filtered based on relevance and match with predetermined keywords. Then, the abstract of each article was screened and scanned according to the pre-defined inclusion and exclusion criteria. A total of 2.495 references were screened based on relevance criteria to the topic. At this stage, some references were excluded, such as books (326) and book chapters (259).

Next, the eligibility involved analyzing 1.383 references to ensure their relevance to the review topic. Articles were analyzed and checked for eligibility using the same software, Covidence. Once the articles were identified as eligible, the full-text was downloaded and the inclusion and exclusion articles were separated. Finally, the inclusion phase resulted in 41 studies deemed relevant for inclusion in systematic review. In this phase, the articles should be able to map the answers to the research questions. This stage showed a significant reduction in the number of references from the identification to inclusion stage, reflecting the rigorous and criteria-based selection.

The determination of inclusion exclusion criteria is a crucial step in ensuring the validity and relevance of the studies to be analyzed in a study. These criteria were designed to screen the literature that meet the specific research objectives, so that only studies that are relevant and appropriate to the topic focus were considered further. The aims to reduce the bias, increase the accuracy of the results, and ensure that findings are reliable and make a significant contribution to the field of study. The following were criteria for articles to be included (inclusion) or excluded (exclusion).

Inclusion and Exclusion Criteria

Table 2. Inclusion and exclusion criteria

Inclusion Criteria	Exclusion Criteria
Article Journal	Book, unit book, proceeding, review
Published articles between 2020 and 2024	Articles not published between 2020 and 2024
Learning approach, learning method and learning media	Evaluation, assessment
Integrated Q1,Q2,Q3	Not integrated Q1, Q2, Q3

Table 2 showed that the inclusion criteria articles published between 2020 and 2024 from indexed journals in Q1, Q2 or Q3 categories. The main focus of selected articles was on learning approaches, learning methods and learning media relevant to the research topic, specifically addressing the integration of ARG and AR in science leaning. These criteria were designed to ensure that only high-quality and relevant articles were considered, providing a solid theoretical and practical basis for further analysis.

Conversely, the exclusion criteria included articles that originated from sources other than journals, such as books, book chapters, proceedings, or literature reviews, as well as articles that were not published in 2020 to 2024 timeframe. Articles that did not

focus on learning approaches, methods or media were also excluded. In addition, journals that were not indexed in Q1, Q2, or Q3categories were considered not to meet the required quality standards. This process aimed to systematically filter the literature, ensuring that only studies that made a significant contribution to the research on the impact of ARG and AR on improving students' SE were further analyzed.

Data Analysis

Analyzing articles were done in two stages. The first was by research theme network mapped. Network mapping was done by VOSviewer software. The result of network mapping by VOSviewer software could be seen in the following picture:

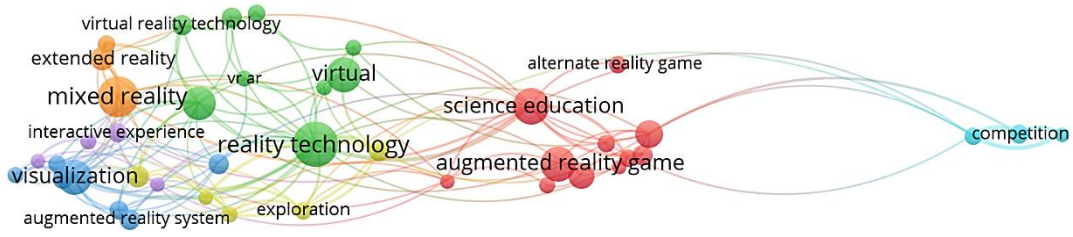

Figure 1. Visualization of initial mapping

Bibliometrics analysis in this network mapping showed the close relationship between the themes of reality technology, gamification and education. Reality technology cluster, virtual reality and mixed reality (green) highlighted the development of reality technology, virtual reality and mixed reality which focused on interactive experience and data visualization. ARG cluster and science education (red) retrieved that there was an integration between AR technology and gamification in education context specially to improve science learning. Moreover, the relationship between visualization and AR system (blue) emphasized the importance of visual aspect in creating a deep educational experience. Other clusters which were related to competition (light blue) highlighted how competitive element in gamification could increase motivation and users' contribution. As a whole, this researched retrieved that reality technology specially AR and VR had essential role in interactive educational, strengthened gamification as an effective pedagogical tool.

Second, full-text articles that met the inclusion criteria were reviewed in depth using the PICO (Participants, Intervention, Comparison conditions, and Outcomes) framework. The determination of statistics in the extraction process depended on the expected trends in the research questions. A manual model based on PICO statistics was used in the data extraction process and continued in the quality study, PICO is a framework used to formulate research questions in the context of systematic reviews. In this systematic literature analysis on the use of Alternate Reality Games (ARG) and Augmented Reality (AR) in science learning, the PICO framework was used to identify and evaluate various aspects of the reviewed studies. First, Participants (P) in these studies generally involved students from different levels of education, including primary, secondary and tertiary schools, with a focus on how ARGs and AR can enhance their engagement in science learning.

Next, the intervention (I) applied in the article includes the use of ARG to increase student engagement in problem solving and AR to provide interactive digital elements. Some studies highlighted the combination of these two approaches, while others only focused on one of methods. In terms of Comparison conditions (C), most studies compared the effectiveness of ARG and AR with conventional learning methods, showing how these innovative approaches can deliver better results. Finally, the outcomes measured (Outcomes, O) in these studies generally related to the improvement of students' self-efficacy, where many articles reported a significant increase in students' confidence in their ability to understand science concepts. Using the PICO framework, this analysis provided a clear picture of the contributions of ARG and AR to the improvement of students' SE in science learning, as well as identifying trends and gaps in existing research (Methley et al. 2014)

▪ RESULT AND DISSCUSSION

Article Literature Mapping

According to searching results from Scopus, Springer, Crossref and Eric databases by using keywords "ARG and AR in Science Education", 2.652 articles were initially identified. After screening process using covidence software, there were 41 articles that fit the criteria. This articles mapping would be detailed about the various attributes including the writers' name, publication year, journal information (journal name, volume, edition, year), type of publication, Scopus accreditation, the relevance of Research Question (RQ) which focused on ARG conflation with AR to increase students' SE in learning science. The following table retrieved articles which fulfilled the inclusion criteria:

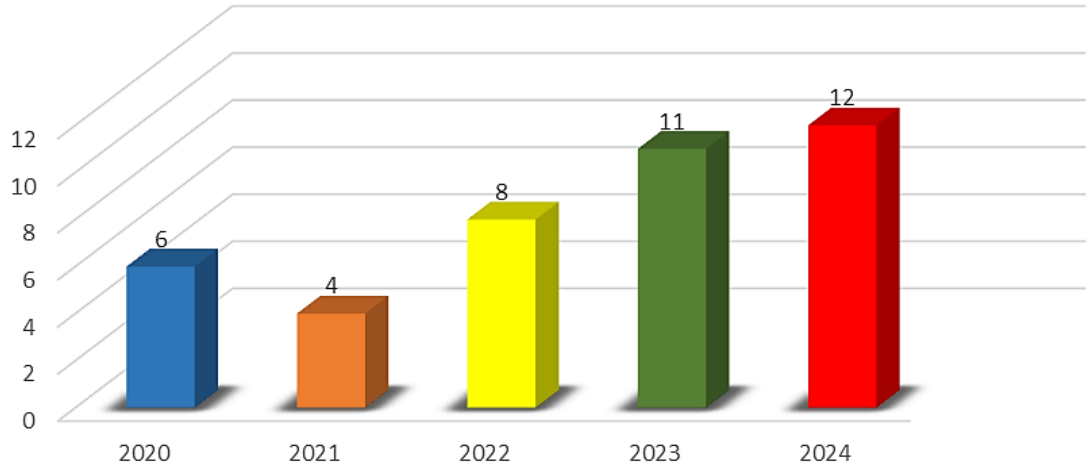

Figure 2. Article year distribution diagram

The diagram above illustrated article distribution which met the inclusion criteria. There were 41. In 2020, there were 6 articles; in 2023, there we 4 articles; in 2022, there were 8 articles; in 2023, there were 11 articles; in 2024, there were 12 articles. The grouping of articles based on the main topics was detailed in the following table.

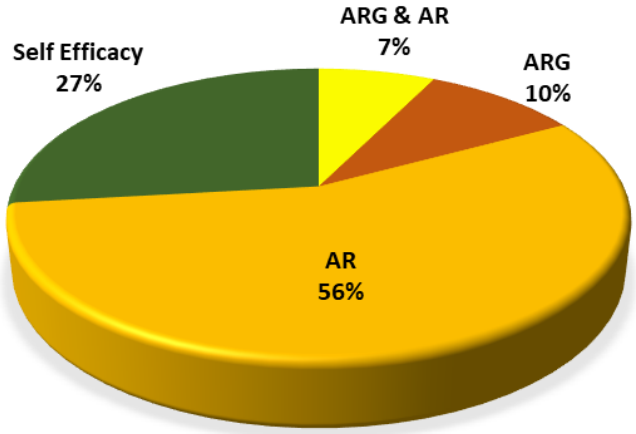

Figure 3. Topic criteria diagram

The second diagram retrieved that there were 7% of 41 articles which were categorized in inclusion criteria. It meant there were 3 articles that met the inclusion criteria. Those 3 articles discussed the combination of ARG and AR topic in science learning. In addition, there were 23 articles or 56% which reviewed the use of AR in science learning. There were 4 articles which discussed about ARG without combining with other approaches and there were 27% articles which explored method and other approaches that had potential to increase students' SE in learning science.

ARG Review toward Increasing Students' SE

The use of ARG in the context of science education provides a teaching method that is not only traditional (Kara, 2021), but also involves students directly and actively (Lin et al, 2024) (Al-Ghizzawi et al, 2024). This approach allows students to explore science concepts through simulations (Tulloch et al, 2021) and interactions that occur in a gamified learning environment (Sofianidis et al, 2024). ARG is designed to increase student engagement through puzzle solving (Binder et al., 2020; Stylinidou et al, 2020), which can improve learning outcomes, as well as strengthen their SE (Elsom et al., 2023), so the integration of ARG in science education plays an important role in developing students' knowledge and skills (Koenit et al, 2024) (Niemeyer et al., 2021). Therefore, ARG provided learning environment that supported the development of SE through skills upgrading, resilience and social support (Sofianidis et al, 2024).

The integration of technology feature in implementing ARG became supporting aspect for students' learning process. One example was the ARG implementation which utilized AI-based chatbot which gave adaptive feedback (Liang et al, 2024). The precise feedback forms this chatbot was essential to increase students' SE because it gave real-time support which allowed direct guidance in facing ARG challenges, gave clear directions, and increased students' confidence in completing tasks (Elsom et al, 2023). Moreover, chatbot encouraged students' regulation skills by facilitating more personal learning and problem solving gradually (Lai et al, 2024). Thus, this AI-based ARG is not only to improve students' learning performance, but also to strengthen confidence towards their SE (Shete et al, 2024).

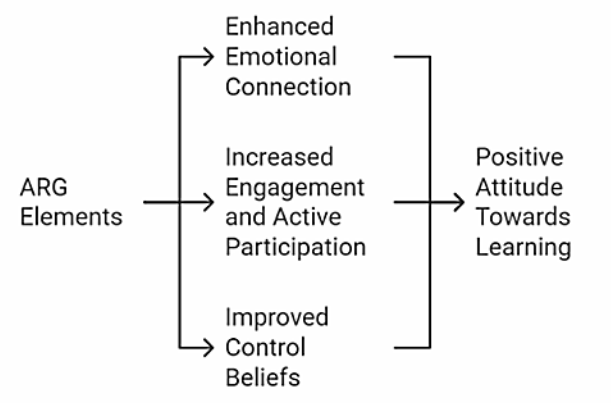

Figure 4. Impact of implementing ARG

Immersive and interactive experiences offered by ARG created learning environment which encouraged active participation from the students in narrative and challenges (Deus et al, 2021), so it could increase their confidence (Hou et al, 2023). By associating learning with real-world situation, ARG assisted students to understand the relevance of knowledge, such as: the implementation of science learning in practical contexts in turn strengthened their academic beliefs (Mao et al, 2021). As a whole, ARG integration in science education contributed in increasing knowledge and students' skills, increased students' SE significantly and created interactive and relevance learning environment (Xiong et al, 2024).

The implementation of ARG in science education offered interactive pedagogical approach and encouraged students' active participation. This approach retrieved huge potential as educational media and entertainment in several countries, including Indonesia. ARG was considered relevant to be implemented in Indonesia because students' characteristics in Indonesia loved gaming activities and often absorbed in immersive play experiences. Based on a survey published by the Indonesian Internet Service Providers Association (APJII) and a report from We Are Social, the level of participation of Indonesian students in the use of digital technology and online games is high (Samsidar et al, 2023). The findings of this study support the effectiveness of ARG implementation in Indonesia, given students' tendencies and habits that are in line with their preferences for digital technology and bold games (Lampropoulos et al, 2024). When students feel more confidents in their abilities, they tend to be more actively engaged in learning (Liu et al, 2024), face challenges with a positive attitude, and achieve better learning outcomes. This suggests that ARG has the potential to be an effective pedagogical tool to improve students' motivation and SE (Sofianidis et al, 2024).

Augmented Reality Review towards SE

AR is a technology which integrates digital elements to the real-world which allows users to interact with inserted virtual account in physical environment, so it creates interactive and immersive learning experience (Cao et al, 2023; Turan et al, 2021). AR provides realistic simulation and interesting visualization (F.N Astuti et al, 2020) of a scientific phenomenon. By multidimensional visualization offered by AR, students could increase better understanding (Baba, 2022), which contributed to SE towards their academic ability (Sánchez et al, 2022; Shakeri et al., 2022).

Researches in developed country, such as: the U.S.A and South Korea revealed that the use of EF effectively increased students' learning motivation and self-efficacy to do challenging science assignments. Wu et al (2023) reported that in the U.S.A, students utilized AR in science learning and their self-efficacy was increase because this technology eased them to understand abstract concepts through visualization directly. In line with the findings, Kim et al (2020) revealed that in South Korea, AR not only encouraged students' active participation, but also increase students' self-confidence in understand complex topic in science. Both researches supported the idea that the AR integrations in science learning was able to be effective tool to strengthen students' self-efficacy, especially to overcome difficult abstract concepts.

AR integration with Multidimensional Concept Maps (MCMs) and Virtual Reality (VR) technology has been shown to encourage students' motivation to actively participate in science learning and to strengthen students' self-efficacy (Yin-Yu Chou, 2021; Chen, 2020). For instance, Yildirim (2020) retrieved how the use of AR could help students to understand differences and similarities of plant and animal cells by looking at structure and organelle function directly in more interactive and safer environment (Shatabdi et al., 2024; Rahmat, 2023). AR was also functioned as catalysator in developing students' self-efficacy by allowing them to observe body organ in 3-dimensions and to interact realistically (Ozcakir et al, 2021; Yildirim, 2021). By safe and realistic learning environment, students could experiment without being afraid to be fail and it could increase students' self-confidence in understanding complex science concepts (Lham et al, 2020; Udeozor et al, 2023).

AR application in science learning, such as three-dimensional model for molecules and biological cells through Holo Lens (Du et al, 2024) allowed students to visualize, to manipulate and to build molecules structure directly and interactively (Yıldırım, 2021). This technology facilitated the understanding of abstract concepts which were difficult to be explained in two-dimensions form, provided opportunities for students to explore complex structures safely without risks and motivated students to experiment without fear of making mistakes (Sivri et al, 2022). Learning supported by AR was likely to increase enthusiasm and students' active participation, so it had positive impact on students' self-efficacy in learning science concept (Yildirim, 2020).

Along with the times, the use of ARG in science learning introduced new integration between AR and game (Tzortzoglou et al, 2023). The use of AR allows students to experience abstract concepts through interactive games which increase students' participation simultaneously and problem-solving skills collaboratively (Özeren, 2023). By integrating AR into game mechanism, students were able to participate into dynamic scientific simulation which was not only making learning to be more interesting, but also enriching students' cognitive experiences through hands-on experience (Khodabandeh, 2022).

AR is effective to be applied for material which needs an explicit visualization, visual and spatial material, such as: anatomy, biology and chemistry because it allows students to interact directly with 3D objects, so it eases them to understand the structures and increases students' SE (Wei et al, 2021). Otherwise, the AR effectiveness decreases in theoretical and abstract concepts, such as: quantum physics and advanced chemistry because those concepts rely on conceptual understanding and mathematics is not always able to be represented visually (López Belmonte et al, 2020). For instance,

electromagnetic field in physics and molecular orbitals in quantum chemistry, AR had limitations since the concepts were not able to be represented intuitively only through visualization (Avila et al, 2021; López Belmonte et al, 2020). Wei et al (2021) revealed that AR was difficult to completely replace essential conceptual reasoning in understanding complex phenomena. AR is more appropriate to be applied for materials which need explicit visualization, while theoretical materials will be better to be taught through problem solving approach or mathematical model (Wei et al, 2021; Ziden et al, 2022).

Although AR has huge potential to increase students' SE, the implementations in developing countries are often hampered by technological infrastructure constraints, limited internet access, lack of financial support and technological awareness. In Nigeria and India, the lack investment of public and private sector, especially in providing digital facilitation and adequate internet connectivity, hinders the widespread of AR adoption (Oke et al. 2022). This condition was aggravated in remote areas which had minimal infrastructures, even though, programs like "Digital India" tries to overcome this gap (Mkwizu et al. 2024). In Tanzania, limited technological literacy is also a major barrier in using AR as a tool of effective learning. To integrate AR optimally in developing countries, significant investment of infrastructure and technology training is needed, but this effort is still difficult to be realized without sustainability support from several sectors (Chasubuta et al, 2024).

Review of ARG dan AR Collaboration towards Students' SE

The merging of ARG and AR created interactive and interesting learning experience (Stylianidou et al, 2020) which was able to increase students' participation in learning process significantly (Llinares, 2023). By narrative integration element of ARG, students were able to feel deeper story where the characters, the objects and the clues could interact in physical environment where they can see through AR device (Xiong et al, 2024). It not only increased students' interest, but also allowed them to engage actively with the lessons material and to strengthen their understanding to the concepts taught (Sofianidis et al, 2024).

AR technology was also functioned to give relevant context with the students' locations which enrich learning experience in science education (Feng et al, 2024). By creating game scenario which taught science concepts through narrative and data visualization, ARG and AR was able to strengthen sense of presence and immersion (Nguyen et al, 2023). This research revealed that this approach not only encouraged exploration, but also increased social interactions among students which it was the essential aspect in learning and developing skills (Zhao et al, 2020; Alharthi et al, 2023).

The use of ARG and AR significantly increased students' SE by providing collaborative and supportive learning experience (Lin et al, 2024). Students learned how to work together in solving challenges, so the were able to increase their self-confidence toward academic skills. Game element and quick feedback in this environment assisted students to recognize the strengths and areas to improve (Stylianidou et al, 2020), so it could strengthen their belief to apply knowledge that has been obtained (Linares, 2023). Therefore, ARG and AR ingratiation in education has potential to create inclusive and efficient learning environment (Stylianidou et al, 2020).

The collaboration of ARG and AR in education has high potential to increase students' SE through interactive and immersive learning experience. However, the implementation in developing countries, such as Indonesia faced significant challenges. One of the challenges was the unequal distribution of technology between rural and urban areas and the limited access to adequate hardware, such as: smartphone or computers with the sufficient specifications (Iswara et al., 2020). In addition, many educators do not get any sufficient trainings to utilize this technology effectively (Oliver Wyman, 2023). Digital infrastructure problem like unstable internet network also becomes constraint in several areas UNESCO, 2023). Therefore, to optimize AR and ARG potential needs comprehensive solutions by more equitable provision of devices, intensive trainings for educators and better improvement of digital infrastructure in all areas of Indonesia.

AR partially has bigger contribution to increase students' SE than ARG. Both ARG and AR technology have been proven to be able to increase students' SE (Valladares et al, 2023), through different mechanism (Hou et al, 2023). AR focusses on improving students' conceptual understanding and encourages active engagement during immersive experiential learning process that allows students to interact directly with the material. As the result, students tend to feel confident in their ability to understand complex concepts, which directly affects their confidence in their academic abilities. AR emphasizes more on improving students' conceptual understanding and active engagement in the learning process (Stylianidou et al, 2020), which in turn contributes to improve their confidence in facing academic challenges (Liang, 2024; Hou et al, 2023). On the other hand, ARG encourages students to think critically, solve problems, and make independent decisions, reinforcing a sense of competence so it is more effective in increasing learning motivation through engaging interactive visual experiences, but its contribution is more limited to the motivational aspect and does not directly increase students' confidence in their abilities. The result showed that the AR's contribution was more focused on the academic aspects in improving SE, while ARH had more significant impact on strengthening social and collaborative skills.

▪ CONCLUSION

According to analysis result, it can be concluded that AR has bigger effectiveness in increasing students' SE in science learning than ARG. AR provided immersive and interactive learning experiences through realistic visualization which allowed students to understand more the complex concepts and to participate actively without risk. Otherwise, although ARG was able to increase engagement and to sharpen cognitive competence, but the contribution was limited to motivational aspects and it did not give significant influence towards increasing students' self-efficacy in academic aspects. Therefore, AR based approach is more superior in supporting students' SE reinforcement in science learning.

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