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Development of Augmented Reality-Based Stem Learning Strategies to Improve Global Competence of Middle School Students in North Sumatra Province

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ABSTRACT: The need to develop learning strategies based on information and communication technology (ICT) is aimed at improving students' global competencies in schools. One way to address monotonous learning and improve student learning outcomes is through the development of learning strategies based on relevant learning media in the current era, namely Augmented Reality (AR)-based Science, Technology, Engineering, and Mathematics (STEM) learning strategies. An opinion survey was conducted through questionnaires and interviews with 30 teachers who were selected proportionally and actively working in secondary schools in the North Sumatra Province. The results of data processing from the needs analysis showed that the needs felt by teachers in managing learning were as follows: there were 26 teachers (86.33%) who felt the need for determining learning outcomes in the realm of high-level thinking skills; 27 teachers (90.33%) felt it was very important to implement STEM learning strategies; 26 teachers (86.67%) stated that it was very important to present factual learning materials based on integrated ICT based on Augmented Reality in the teaching and learning process; 22 teachers (86.66%) also stated that learning strategies with an active student learning approach through problem-based learning were very important to support the implementation of an effective, efficient and attractive learning system. 28 teachers (93.33%) stated that developing learning materials required building students' reasoning both inductively and deductively based on science and technology as well as research results to improve students' global competence; Communication in the form of social media networks was felt by 25 teachers (83.33%) to be very important to support collaboration and cooperation between students.

KEYWORDS: Learning Strategy; STEM; Augmented Reality; Global Competence; MiddleSchool Students.

INTRODUCTION

Global competence demands a variety of abilities and skills to solve current and future problems. Meanwhile, the real-world learning environment in schools is dominated by teachers, with students following their own learning patterns. Learning strategies developed in the past may not be relevant to the characteristics of today's students. This is supported by research by Illkou et al. (2021), which states that learning systems need to address technological developments and the need for personalized learning in the digital era. Innovation in learning strategies is needed to enable learning processes to occur in dynamic, not static, environments. The ever-changing world, particularly as a result of globalization and the digital revolution, demands adaptable learning systems where students learn actively and creatively.

Knowledge is not transferred linearly from teacher to student, but rather is actively constructed by students themselves through learning experiences. In modern constructivist theory, students are active subjects who construct meaning through social interactions and learning contexts. Daodu et al. (2024) explain that constructivist-based learning has been shown to significantly increase student participation and critical thinking skills. However, teachers often tend to use self-centered learning strategies.

The development of learning strategies aims to enhance educational value, including the efficiency, effectiveness, and relevance of learning. These values are essential for education to produce not only knowledge but also meaningful character and competencies for students (Saavedra et al., 2023; Yazigy, 2023). In this context, learning strategies should not solely pursue academic achievement but should also facilitate the formation of moral, social, and cultural values.

Interviews revealed that many teachers experience challenges in carrying out their profession effectively. Consequently, when the quality of educational processes and outcomes is low, teachers often shift responsibility to others, such as parents, the environment, and so on. The emerging issues include low levels of teacher professional competence and low student competency and learning outcomes in facing global challenges.

This is supported by research by Daodu et al. (2024), which revealed that most learning frameworks in educational institutions have not comprehensively integrated the values of interactivity, collaboration, and technology into learning.

Consequently, there is a dissonance between the theory taught and the learning practices students experience in real life. A report by Schmalzle et al. (2024) in the OECD (2024) states that there is still a gap between research findings and implementation in schools, hampering educational innovation at the grassroots level. A study by Alismaiel et al. (2022) shows that integrating technology such as online learning and social media can improve student engagement and learning outcomes by supporting a constructivist approach.

In general, teachers' abilities, particularly those related to learning strategies, show very concerning symptoms. This is indicated by noisy or rowdy classrooms, and students' lack of seriousness and discipline during the learning process. Most teachers still face significant challenges integrating information and communication technology and developing AR-based STEM learning strategies, while simultaneously organizing and coordinating students' commitment to completing their learning assignments.

The question is: What learning strategies do teachers need to create learning spaces and conditions that support active and creative student learning experiences and enhance their global competencies?

Theoretical Study

Maslow explained that humans have various needs arranged in a hierarchy, from the most basic to the most complex. These needs, if not met, will motivate individuals to seek them, and when the needs are met, the motivation will diminish. Maslow believed that individuals are motivated to fulfill the needs at each level before moving on to the next. However, he also acknowledged that these needs are not always met gradually and that individuals can regress to a lower level if these needs are not met. This also occurs in the school environment, where the motivation of teachers and students to achieve learning outcomes in the form of mastery of global competencies through the development of learning strategies integrated with science, technology, engineering, and mathematics is a crucial need for self-actualization. Furthermore, a flexible learning process is needed, utilizing learning media that can present subject matter in a more realistic and factual manner, making it easier for students to interpret and master the established competencies.

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The development of learning strategies aims to enhance educational value, including the efficiency, effectiveness, and relevance of learning. These values are essential for education to produce not only knowledge but also meaningful character and competencies for students. In this context, learning strategies should not only pursue academic achievement but also facilitate the formation of moral, social, and cultural values.

Needs Analysis for Developing Augmented Reality-Based STEM Learning Strategies

STEM learning strategies are currently an alternative to science learning that can build a generation capable of facing the challenges of the 21st century (Hannover, 2017). The need to introduce STEM learning strategies is crucial for developing 21st-century skills in students. Students must be able to think critically and dynamically in applying science, technology, engineering, and mathematics (STEM) to solve complex problems. Without developing key 21st-century skills (such as critical thinking, problem-solving, and teamwork) and STEM learning strategies, students will struggle to compete in the fast-paced Industry 4.0 era. Through STEM learning strategies, teachers can engage students by utilizing modern pedagogy, which is expected to enhance students' complex global competencies.

Research shows that STEM implementation can improve students' academic and non-academic achievement (Pamela W. Garner 2017). Therefore, STEM implementation, which initially aimed only at increasing student interest in STEM fields, has become broader. STEM learning strategies can be combined with problem-based learning that can be observed contextually and conditionally. STEM is built on a multidisciplinary approach integrated into problem-based learning strategies and everyday contextual events. STEM learning strategies apply knowledge and skills simultaneously to solve problems in an effort to improve global competence. Torlakson (2014) outlines the aspects of STEM as follows: Science, which provides students with knowledge and frameworks regarding the laws and concepts that apply in nature; Technology, which is a form of skill for managing a system used in organizing society, organizations, or designing and using artificial tools that can facilitate work; Engineering, which is a form of mastery of knowledge to operate or design a procedure to solve a problem; Mathematics is a science that connects quantities, numbers, patterns and space which only requires logical thinking patterns without or accompanied by empirical evidence.

As social beings (Vygotsky, 1978), analysis shows critical thinking skills as an essential part of the human cognitive process. Learning videos should be the primary medium for learning because they must contain content that is not only informative but also inspiring and transformative. They should foster noble values and encourage students to continue learning and development (Deci & Ryan, 2017).

This theory is combined with the Critical Thinking Framework developed by (Paul & Elder, 2019), which emphasizes the importance of learning critical thinking skills through a comprehensive process of absorbing, reasoning, and problem-solving. The differentiation component is based on the theory of multiple intelligences by

(Gardner, 2011) and differentiated instruction by (Tomlinson, 2014), which recognizes that each student has unique learning strengths and preferences, thus requiring diverse approaches to content, procedures, and learning products. Social learning theory developed by (Bandura, 1977) centers on interactive and partner-based components, which state that learning occurs through observation, imitation, and modeling in a social context. The cooperative theory developed by (Johnson & Johnson, 2014) identifies five essential components of cooperative learning: positive interdependence, individual accountability, face-to-face interaction, social skills, and group processing. Students' problem-solving skills are one strategy teachers can use to shape students' critical thinking patterns.

Various learning models that can be applied to build and develop STEM learning strategies include: Discovery learning, emphasizing the discovery of previously unknown concepts or principles with a focus on problems engineered by the teacher. The application of the Discovery Learning learning model emphasizes the role of the teacher as a guide by providing opportunities for students to learn actively. Inquiry Learning, focuses on students finding problems so they must use all their knowledge and skills to find findings in the problem through the research process. Problem Based Learning, is learning that uses various thinking abilities of students individually or in groups as well as real environments to solve problems so that they are meaningful, relevant, and contextual. Project Based Learning, uses projects/activities as the core of learning. Students use problems as a first step in collecting and integrating new knowledge based on their experiences in real activities.

Augmented Reality-Based STEM Learning Strategies

Currently, context- and environment-based STEM learning strategies are becoming a preferred approach to improving human resources. The demands of the 21st-century workplace require education to evolve and learning to be meaningful. Various learning strategies will continue to be developed as needed and to ensure learning meets objectives. Hwang & Chang (2011) Adaptive learning algorithms that utilize differentiation features can change the content, pace, and complexity of videos based on analysis of individual student learning behaviors (Siemens & Long, 2011). Interactive components are supported by VR and AR integration, allowing students to interact directly with objects in the video. Meanwhile, Line Partner is facilitated by a synchronized collaborative viewing platform, allowing students to pair up to watch and listen to videos in real time, wherever they are (Clark & Mayer, 2016). Thus, to be able to think critically, students must be able to analyze tasks and reconstruct steps as a procedure for solving problems in the form of video tutorials integrated with AR.

Augmented Reality is a technology that combines the real world with virtual or digital elements, creating a unified experience between the physical and digital worlds. By using devices such as smartphones or tablets, users can see and interact with virtual objects that are "projected" into their real environment. As explained by (L. N. Sari et al., 2023), augmented reality allows students to learn directly from their surroundings, presenting additional or interactive information that cannot be obtained from traditional learning media. Augmented Reality (AR) is a technology with a real-time and digital merging system of computer- generated content with the real world. Augmented Reality can be used by users to see 2D or 3D virtual objects projected onto the real world. Augmented Reality (AR) according to Brian (2012) is a term related to an environment that combines the real world with a visual world created by a computer, making the boundaries between the two very thin. This system is more directed towards a real or real environment, reality prioritizes this system. This technology combines digital elements, such as 3D images, animation, and video, with the real world, allowing students to see and interact with concepts that might have previously been difficult to imagine. This technology can bring new colors to the field of education, Azuma (1997). According to Martín-Gutiérrez & Contero (2011), Augmented Reality aims to use the real world as a basis for combining various virtual technologies and adding conceptual data to enhance understanding and clarity for users. This conceptual data can be in the form of comments, audio, location data, historical context, or other forms. The infrastructure needed to install an AR system in the classroom is a computer, webcam, and projector. Teachers manipulate virtual objects and can interact with them to support their explanations. Students' books or class notes are equipped with appropriate markers so they can interact with additional and visualized information. Students can visualize information on a PC or in an AR application developed for smartphones running Android and iOS. Its use is not only focused on insight but also touches the emotional side of students. According to (Marc, 2001), interactive technologies, such as AR, have great potential to increase student engagement especially for abstract material. The experience stimulates their brains to absorb knowledge more progressively. This technology inserts information into a virtual world and then displays it in the real world with the help of special tools. Typically, these tools include cameras, computer webcams, and some even use special AR glasses. Research conducted by Jorge et al. (2014), which analyzed 32 journals, indicates that AR technology is chosen to motivate students to learn. The benefits experienced by users include increased interaction, collaboration, and enthusiasm for learning. Research by Pratama (2023) shows that the use of augmented reality in mathematics learning improves students' learning motivation and academic outcomes.

This is in line with the research findings of Masri et al., (2023) on the use of augmented reality in science learning, where students showed increased conceptual understanding and interest in the subject matter. Therefore, in general, augmented reality has great potential as an innovative and effective

learning tool. With Augmented Reality technology, the real environment around us can interact in digital (virtual) form. Information about objects and the environment around us can be added to the augmented reality system, which then displays this information on the world screen in real time as if the information were real. "Augmented Reality: a new lens for watching the world" - as reported (Ariel, 2011). AR is seen as an educational intervention that aims to shape students' mindsets, attitudes, and skills in critical and structured thinking. AR- based learning strategies are developed based on the fact that learning begins with a factual introduction of problems that are demonstratively adapted to digital-native characteristics, information speed, and practical and visual tendencies.

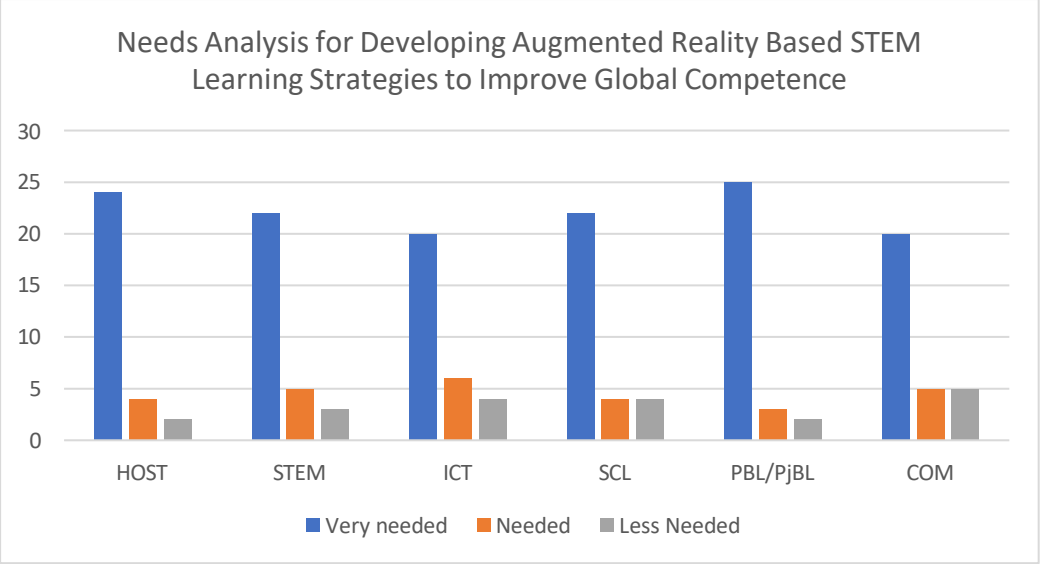
RESEARCH METHOD

This research approach uses the Borg & Gall (2003) development model combined with the Dick & Carey (2005) learning design model. The study population was all teachers registered and active in the learning process at school. The sample consisted of senior high school (SMAN) and vocational high school (SMKN) teachers in three cities/regencies: Medan City, Langkat Regency, and Toba Regency, North Sumatra Province. Data collection techniques were questionnaires, interviews, and document recording.

RESEARCH RESULTS

The needs analysis on "Developing Augmented Reality-Based STEM Learning Strategies to Improve Global Competence in Secondary School Students in North Sumatra Province" was conducted through questionnaires and interviews with 30 public high school and vocational school teachers in North Sumatra Province, selected proportionally.

The results of data processing from the needs analysis show that the needs felt by teachers in managing learning are as follows: there are 22 teachers (73.33%) who feel it is very important; 4 teachers (13.00%) who feel it is important; and 2 teachers (6.70%) who feel it is less important, to determine learning outcomes in the realm of high-level thinking skills to improve students' global competence in the form of problem solving. 22 teachers (73.33%) are very important for the implementation of STEM learning strategies; 5 people feel it is important (17.00%); 3 teachers (10.00%) who feel it is less important. 20 teachers (66.67%) stated that it is very important to present factual learning materials based on integrated ICT based on Augmented Reality in the teaching and learning process; 6 teachers (20.00%) who feel it is important; and 4 teachers (13.33%) who feel it is less important. 22 teachers (73.33%) also stated that the learning strategy with an active student learning approach through problem- based learning is very important to support the implementation of an effective, efficient and attractive learning system; 4 teachers (13.33%) felt important; and 4 teachers (13.33%) felt less important. 25 teachers (83.33%) stated that developing learning materials requires building students' reasoning both inductively and deductively based on science and technology and research results to improve students' global competence; 3 teachers (10.00%) felt important; and 2 teachers (6.67%) felt less important. Communication in the form of social media networks was felt by 20 teachers (66.66%) to be very important to support collaboration and cooperation among students. 5 teachers (16.67%) felt important; and 5 teachers (6.67%) felt less important. The following describes the analysis of the need to develop augmented reality learning strategies to improve the global competence of high school students in North Sumatra Province:



HOST : High Order Thinking Skill
STEM : Science Technology Engineering Mathematics

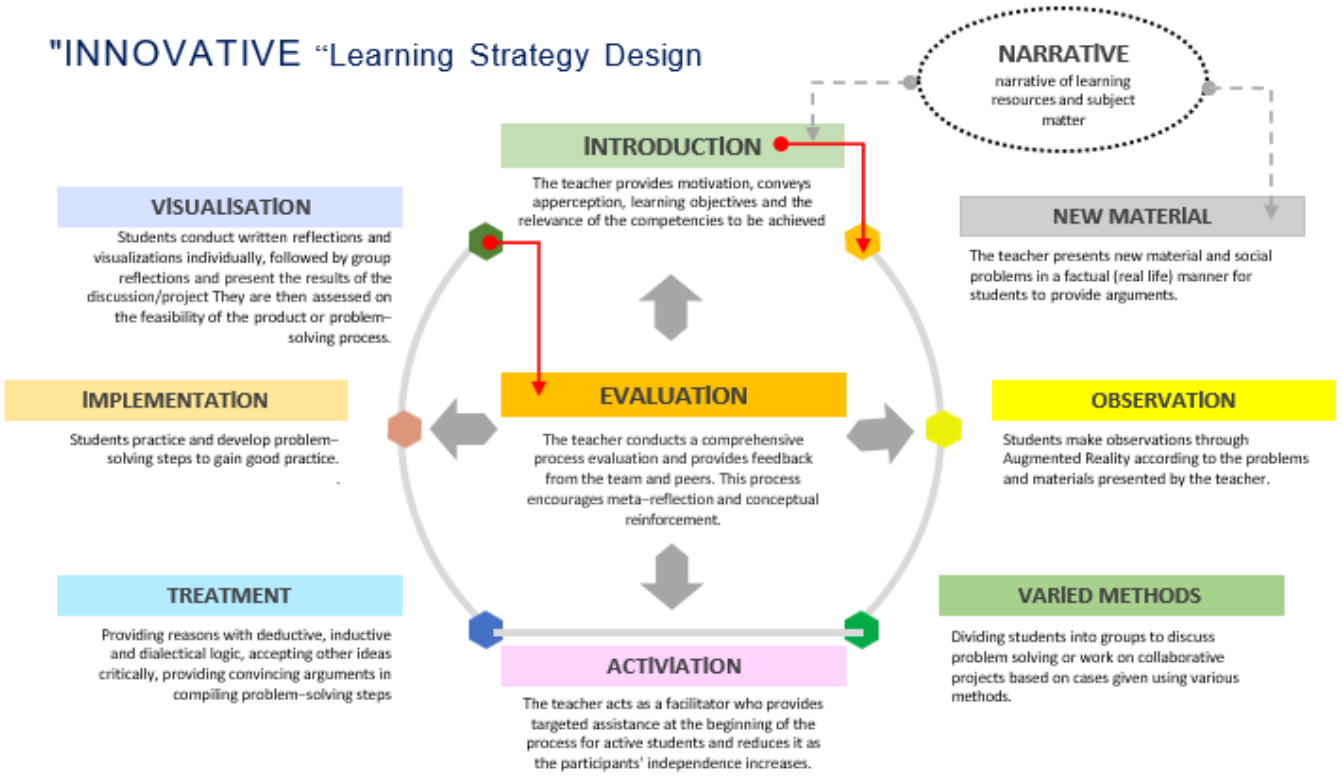
ICT: Information Communication and Technology
SCL: Student Center Learning
PBL: Problem Based Learning
PjBL : Project Based Learning
COM : Communication

The phenomenon in the field shows that not a few teachers who initially had very good performance in designing learning strategies but when faced with learning strategies integrated with technology, teachers then become stuttered in implementing them in the classroom. Generally, teachers feel a lack of skills in using Augmented Reality in presenting lesson materials in class; Support facilities for the implementation of AR-based STEM learning are very minimal, making it difficult for teachers to adopt and innovate in adding new lesson materials to improve student competencies; In practice, teachers do have a strong attraction to be able to use technology in learning, but sometimes the reality is found that learning practices are still teacher-oriented so that student activity becomes very passive. In practice, teachers have not been able to design and develop AR-based STEM learning strategies and have not been able to ensure that learning outcomes still tend to be formulated in the realm of low-level thinking skills and are not measurable. Furthermore, teachers need assistance in compiling and developing AR-based STEM learning strategies as a synergistic system to encourage interaction and integration between teachers, students, and media in achieving learning objectives. Teachers believe in the importance of the active role of all components or members of the school community to improve students' global competencies. Therefore, teachers feel the need to be open and open a network of collaboration on practices applied in managing their learning in class.

Initial Design of an Augmented Reality-Based STEM Learning Strategy

The STEM learning strategy is an integrated approach to solving real-world problems by integrating Science, Technology, Engineering, and Mathematics. It aims to develop critical thinking, creativity, collaboration, and problem-solving skills in students through experiments, design, and data analysis activities that encourage active participation and in-depth learning. 2 The STEM (Science, Technology, Engineering, and Mathematics) approach, integrated with PBL, PjBL, and Blended Learning models, applied to mathematics learning, can influence the improvement of students' critical thinking skills.

The initial design of the AR-based STEM learning strategy is shown in the following figure:



Syntax of the "INNOVATIVE" Learning Strategy

LEARNING STEPS	SERIES OF LEARNING ACTIVITIES
Introduction	The teacher provides motivation, conveys apperception, learning objectives, and the relevance of the competencies to be achieved.
Narrative	A narrative of learning resources and subject matter.
New Material	The teacher presents new material and social issues factually (from real life) so that students can provide arguments.
Observation	Students conduct observations through Augmented Reality based on the problems and material presented by the teacher.
Varied Methods	Students are divided into groups to discuss problem-solving or work on collaborative projects based on given cases using various methods.
Activiation	The teacher acts as a facilitator, providing targeted assistance early in the process for active students and reducing this assistance as the participants' independence increases
Treatment	Provides reasons using deductive, inductive, and dialectical logic, critically accepts others' ideas, and provides convincing arguments in developing problem-solving steps.
Implementation	Students practice and develop problem-solving steps to gain good practice.
Visualisation	Students conduct written reflections and visualizations individually, followed by group reflections and presentations of the results of their discussions/projects. They are then assessed on the feasibility of their products or problem- solving processes.
Evaluation	Teachers conduct comprehensive process evaluations and provide feedback from their teams and peers. This process encourages meta-reflection and conceptual reinforcement.

CONCLUSION

Based on the results and discussion outlined above, the following conclusions are
drawn:

1. The AR-based STEM approach is aimed at enhancing students' creativity, conceptual mastery, and digital literacy. The learning strategy stages are developed based on social constructivist learning theory and cognitive development, which facilitates the development of student creativity by creating an environment that combines science, technology, engineering, and mathematics to complete projects based on selected problems.
2. The learning strategy used is called "INNOVATIVE" consisting of ten stages of learning, namely: 1) Introduction: The teacher provides motivation, conveys apperception, learning objectives and the relevance of the competencies to be achieved;

2) Narrative: narrative of learning resources and lesson materials; 3) New Material: The teacher presents new materials and social problems factually (real life) so that students can provide arguments; 4) Observation: Students make observations through Augmented Reality according to the problems and materials presented by the teacher;

5) Varied Methods: Divide students into groups to discuss problem solving or work on collaborative projects based on cases given using various methods; 6) Activation: The teacher acts as a facilitator who provides directed assistance at the beginning of the process for active students and reducing it as the participants' independence increases;

7) Treatment: Providing reasons with deductive, inductive and dialectical logic, accepting other people's ideas critically, providing convincing arguments in compiling problem-solving steps; 8) Implementation: Students practice and develop problem- solving steps to get good practice; 9) Visualization: Students conduct written reflections and visualizations individually, followed by group reflections and presenting the results of the discussion/project. They are then assessed based on the feasibility of the product or problem-solving process; 10) Evaluation: The teacher conducts a comprehensive process evaluation and provides feedback from the team and peers. This process encourages meta-reflection and conceptual strengthening.

3. Factors that influence the improvement of critical thinking skills through the STEM (Science, Technology, Engineering and Mathematics) approach are: a. Internal factors include students' abilities, motivation and student activity b. External factors include the learning environment conditions and teaching materials provided by the teacher.

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