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Development of Augmented Reality Based Stem Learning Models and Innovations for Improving Global Competence of Middle School Students in North Sumatera Province

Efendi Napitupulu[1], Nono Sebayang[2], Enny Keristiana Sinaga [3]

[1,2,3] *Lecturer at the Faculty of Engineering, Medan State University*

Abstract. Developing a STEM learning model as a supporting component for improving students' global competence today and in the future that is integrated with Augmented Reality (AR) based learning media is needed to make it easier for students to master abstract subject matter. The purpose of this research is to produce STEM learning models and AR learning media products that are developed through science, technology, engineering, and mathematics innovations in class XI subjects at State High Schools of North Sumatra Province that are feasible and effective. Assessment of the development of AR learning media models and products is carried out by conducting a feasibility test and testing the effectiveness of learning models and media. The results of media validation by material experts and learning media experts showed that the product was very feasible to use.

Keywords: Development of STEM Learning Models and Innovations; Augmented Reality Learning Media; Feasible and Effective; State Middle School Students of North Sumatra Province.

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1. Introduction

Global competency is a key priority for enhancing human resource capacity in Indonesia at the beginning of the 21st century. This competency is a guide to training people with the necessary skills to be competitive in the world of work. 21st-century learning is one way to realize the perfection of these skills to solve resource quality problems.

Indonesia`s human resources with the Human Development Index (HDI) in Indonesia amounting to 72.91 points in 2022. This score increased by 0.86% compared to the previous year, which was 72.29 points [1]. Based on the research conducted by the OECD, a description of three (3) dimensions of learning in the 21st century was obtained, namely information, communication, ethics, and social influence [2]. Creativity is also an important component in facing a complex world successfully [3].

The Partnership for 21st Century Skills (P21), based in the United States, identifies essential skills for the 21st century, specifically the "4Cs": communication, collaboration, critical thinking, and creativity. It is important to teach these skills to students in the context of core learning areas and 21st-century topics. Assessment and Teaching of 21st Century Skills (ATC21S) categorizes skills in the 21st century into 4 (four) categories, which are ways of thinking, ways of working, working tools, and skills for living in the world [4].

In 21st-century learning, there are six most important skills to teach students. With these six skills or abilities, students can overcome any challenges**.** The 21st-century skills known as the "6Cs" include creative thinking, critical thinking, problem-solving, communication**,** and collaboration. Character and citizenship. Researchers and education experts have identified the C- standards of 21st-century education, which include critical thinking, collaboration, communication, creativity, citizenship/culture, and character education /connectivity [5];[6].

For 21st-century learning, schools must develop models of science, technology, engineering, and mathematics (STEM) learning and innovation that teachers can use to nurture a student system [7]. Teaching STEM through digital technology today is essential for future student

Figure 1. Global Competence

Source: OECD, https://www.oecd.org/pisa/innovation/global-competence/

Students who possess global skills can think critically and creatively by considering a variety of previous approaches and the perspectives of others. They act ethically and collaboratively (innovatively) to contribute to local, regional, or global development. Students with global skills do not consider themselves capable of solving complex challenges alone. However, they may reflect on their ability to complete assigned tasks and seek opportunities to collaborate with others to complement their strengths.

Mutual respect and tolerance are essential to ensure that the views of individuals of all cultures are recognized and respected in a multicultural society. It is very important that students learn to listen to others, be flexible, and work together with contributors in teams from different cultures and fields of knowledge. This is a very important skill that 21st-century society should not ignore [10]. There are several connections between the three forms of literacy, including information, communication, m edia, and technology. Mastery of these skills enables mastery of other skills and competencies needed to succeed in life in the 21st century [11]. The International Commission on Education for the 21st Century has proposed four visions of learning: knowledge, understanding, life skills, and action skills. Besides this vision, four principles were also formed, known as the four pillars of education, which are learning to know, learning to do, learning to be, and learning to live together [12].

UNESCO has identified 18 IT skills teachers should aim for and divided them into 64 specific goals. Skills range from encouraging teachers to understand national priorities as identified in the National ICT Policy in Education to how ICT can support the curriculum, assessment strategies, methods of pedagogy, school and classroom organization, management, and continuous professional development [13].

On this basis, it is clear that education has an important, even fundamental, role in providing 21st -century students with the opportunity to develop skills that allow them to live peacefully within cultural conditions and diversity (Carneiro and Draxler, 2008). According to the above, 21st-century skills are divided into three

categories:

1) Learning skills

Study skills are skills that form learning skills. In this case, learning skills emphasize 21st - century skills, including the 4Cs (creative thinking, critical thinking, communication, and collaboration). Study Skills (4Cs) teach the mental processes needed to adapt and improve in the modern work environment. The reason is that critical thinking can help solve problems and find solutions. Meanwhile, creativity is used to find innovation. Cooperation and communication are used to have the ability to interact with others.

2) Literacy skills

Literacy skills focus on how well you can discern the truth, identify sources of information, resist misinformation (hoaxes), and know the technology behind it. This skill is essential in the rapidly evolving information age. There is a lot of information flooding the Internet, so you need to have skills in organizing and checking whether the information is accurate. The three 21st-century literacy skills (literacy skills) are Information literacy, understanding facts, figures, statistics, and data; Media Literacy, understanding methods and channels through which information is published; and Technological Knowledge, understanding of the machines that produce information.

3) Life skills

Life Skills focuses on gaining survival skills and improving the quality of your personal and professional life. These skills can help and influence your career. Skills included in life skills include Flexibility, the ability to adapt easily and adapt when plans do not go as expected; Leadership: leadership is important in motivating a team to achieve its goals; Initiative: Initiate one own projects, strategies, and plans; Productivity: the ability to remain productive in a work environment full of distractions Social skills: the ability to socialize and connect with others for mutual benefit.

11. STEM Learning Model

21st-century learning is learning that combines three global skills, which are study skills, literacy skills, life skills, skills and attitudes, and technological proficiency. STEM-based learning models simultaneously apply knowledge and skills to accomplish something. This approach is presented as a 21st-century learning approach to create quality human resources in cognitive, psychomotor, and emotional skills [13].

Using a "questions first" approach, adaptive learning explores what students know and have mastered and where they are lacking and need instructional support. Through the right programs of study, adaptive learning can strengthen 21st-century skills and provide new knowledge about company-specific products, services, and processes. Adaptive learning is an educational method that allows students to learn and progress through lessons at their own pace. In the context of primary and secondary education, STEM ed ucation aims to develop students proficient in STEM [14] with the following details: First, have the knowledge, attitudes, and skills to perceive questions and problems in their life situations, explain phenomena, design and draw evidence-based conclusions about STEM-related issues. Second, understand the specific characteristics of STEM subjects as human-initiated forms of knowledge, research, and design. Third, people know how STEM subjects shape the physical, intellectual, and cultural environment. Fourth: the desire to research STEM-related issues (e.g., energy efficiency, environmental quality, limited natural resources) constructively, caring, and thoughtful, using ideas from science, technology, engineering, and mathematics. Using a STEM approach to learning allows students to understand that concepts, principles, and techniques from science, technology, engineering, and mathematics are used in an integrated way in the development of products, processes, and systems and can especially inspire students to find suitable solutions that can be used in their everyday lives. In the learning process, STEM may only partially and comprehensively represent some elements of the sciences. There may be only 2 or 3 elements in a learning activity, and there is no rule that all elements must be present.

There are six key steps that education stakeholders must follow to achieve STEM education [15]. The six steps are: Apply rigorous math and science standards and improve assessments; Place and retain more qualified teachers in the classroom; Provide more rigorous preparation for STEM students; Use informal learning to extend math and science beyond the classroom; Improve the quality and supply of STEM teachers;

and setting goals for post- secondary institutions to meet STEM employment needs.

1.2. Augmented Reality

To achieve global competence, 21st-century learning emphasizes higher-order thinking (HOTS), or a learning process that involves elements of higher-order thinking. Typically, 21st- century learning uses project-based methods (Project-Based Learning) or Inquiry-Based Learning. The highest function of education is to form a well-rounded individual capable of facing life in general [16]. Adapting new knowledge and integrating it into existing conceptual frameworks will support continuous learning and, over time, will give rise to creativity, originality-defining habits, and new awareness. Learning creates an active and productive learning community that can support deeper learning through the acquisition of content knowledge and the development of personal and interpersonal skills [17]. Teachers can use student responses to assess their readiness for deeper learning and introduce appropriate new concepts to challenge their thinking.

Using technology in the classroom requires easy-to-use tools that are necessary to ensure engaging technology can deliver rich and reliable experiences for teachers and students. Augmented Reality or AR is a technology that combines real-time digital content created by a computer with the real world. Augmented Reality allows users to see 2D or 3D virtual objects projected onto the real world. AR can be displayed on various devices such as cellphones, special glasses, cameras, screens, webcams, and so on. These devices will function as output devices. Why output devices? Because it will display information in the form of videos, images, animations and 3D models that need to be used. Augmented Reality or AR uses SLAM (Simultaneous Localization and Mapping) technology, sensors and depth meters. For example, collecting sensor data to determine a location, calculating the distance from a previous location to a destination location, and so on.

Keller [18] states that “instructional designers are faced with even greaterchallenges in self -directed learning environments than with traditional instruction, especiallywith regard to satisfying the motivational needs of learners.” Thus experienced teachers must ultimately reconstruct their knowledge of practice for teaching through "systematic inquiry into teaching, students and learning, subject matter, curriculum, schools and schooling. Learners need practical experience to question and reflect in ways that conflict with the concept of knowledge - their existing practices while integrating technology in their teaching [19]..

Saavedra and Opfer suggest nine principles for teaching 21st century skills: (1) make learning relevant to the 'big picture'; (2) teaching 10 with discipline; (3) develop lower and higher thinking abilities to promote understanding in different contexts; (4) encourage learning transfer; (5) teaching how to 'learn to learn' or metacognition; (6) correct misunderstandings directly; (7) promoting teamwork; (8) utilizing technology to support learning; and (9) increasing student creativity. What forms of pedago gy have the most potential to empower critical competencies and skills in a complex and uncertain future? [20].

2. Research Methods

The research approach used in this research is development research (Research & Development) by combining Dick & Carry's learning system design steps with the Borg & Gall research and development model. Borg & Gall [21];[22].. The results of developing a STEM learning model based on Augmented Reality can be described and referred to as the OMCDE learning model.

2.1. Development of an Augmented Reality Based OMCDE Learning Model

The OMCDE learning model has been designed and presented to help students understand the events around them so that students get real learning experiences from their own environment and enabling students to establish human and communicative relationships. with other people. This learning model also provides feedback in the of evaluation so that teachers can measure students' abilities after the learning process. There are several stages in the OMCDE learning model that will be carried out as steps in realizing the learning process as can be seen in Figure 1.1 below:

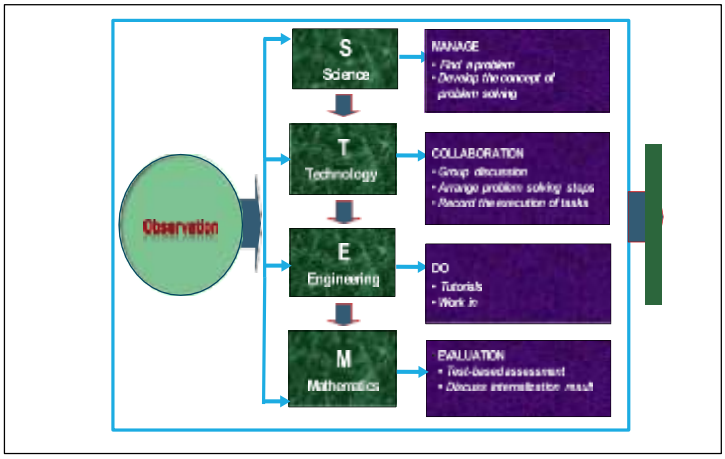

Figure 1.1 OMCDE Learning Model

The syntax for the steps in implementing the OMCDE learning model can be explained as follows:

1) Observation:

At the beginning of learning, the teacher gives students the opportunity to make extensive observations of issues related to the surrounding environment. This aims to build a dynamic learning atmosphere, full of enthusiasm and enthusiasm for understanding current and future problems. Psychologically, students are said to be ready to take part in learning, characterized by high motivation, enthusiasm, passion shown by a cheerful and attentive attitude when starting the learning process through initial knowledge from observations made of the environment and conditions that are occurring in front of them. In order to prepare these conditions, apart from conducting apperception, teachers can start the learning process by giving students the opportunity to express their opinions regarding the results of their observations and the learning objectives.

2) Manage:

Students must be able to manage their thinking patterns related to various information and problems based on the results of observations and at the same time analyzed as a form of facts, concept formation, procedures and metacognition so that a scientific construction is obtained in the form of material substance that will be presented in the teaching and learning process so that students can connect the learning material with science (science). Learning materials are selected as optimally as possible to help students achieve competency standards and basic competencies. Things that need to be considered regarding the selection of learning materials are the type, scope, sequence and treatment of the learning materials.

3) Collaboration:

Collaboration means that a group of people can work together in a coordinated manner to achieve a common goal through certain media. Each student can develop their capacity to create the results they really want through group discussions to exchange opinions in order to increase new thinking and develop collective thoughts and aspirations that develop freely and where students collectively and continuously carry out learning together.

4) Do:

In the learning process, students must experience what they learn and must be able to take action, so that students have experience and are brought to their original situation or job market. Learning by using various things around students through their experiences will indirectly create meaningful and enjoyable learning so that the expected learning objectives will be easily achieved. Even through learning by doing activities, students will be involved in the learning process spontaneously. This stems from a sense of curiosity and practice by students regarding things they don't yet know, encouraging active involvement in a learning process.

5) Evaluation:

Evaluation is used as a measuring tool to determine the level of achievement of the results obtained by Pegaseanf on the materials that have been presented, so that with evaluation the learning objectives can be known accurately and convincingly. In conditions where students get satisfactory grades, it will have an impact in the form of a stimulus, motivator so that students can further improve their achievements.

In the evaluation process teachers can find deficiencies in the learning process. Apart from students being able to know the extent of success they have achieved while attending education, a teacher must be responsible for improving his teaching, so the teacher must evaluate his teaching so that he can make changes to what should be made. In conditions where the results achieved are not satisfactory. So students must also try to improve their learning activities, however, it is very necessary to provide positive stimulus from the teacher so that students can improve their learning, both in groups and individually.

22. Validation of the OMCDE Learning Model

The expected result from developing this OMCDE learning model is that this learning model can be used in the learning process by integrating STEM, namely a form of science or knowledge obtained from observations of the surrounding environment until questions arise as a form of problem for which a solution will be sought; technology in the form of concepts formed as a basic basis for solving problems; engineering in which there is a pattern of critical and independent thinking so that students have space to develop their creativity which can create an appropriate procedure for solving the problem posed; Mathematics as a basis for consideration in making the right decisions in carrying out actual practice so as to obtain a product that can be used in everyday life.

23. Feasibility of the ABCD Learning Model

Based on the validation results from instructional design experts, it can be concluded that the validation score interval by instructional design experts of 4.03 is included in the "good" or "decent" category. The following are the results of validation by instructional design experts in the form of a bar chart in Figure 1.2 below:

Figure 1.2 Bar Diagram of Validation Results of the OMCDE Learning Model by Instructional Design Experts

24. Practicality of the OMCDE Learning Model

Based on the assessment score interval for the initial practical field trial for teachers teaching at State High Schools and Vocational Schools in Balige, it was 3.97 and was included in the "very practical" criteria. Below are presented the results of the assessment score intervals for the initial practical field trials in the form of a bar chart in Figure 1.2 below:

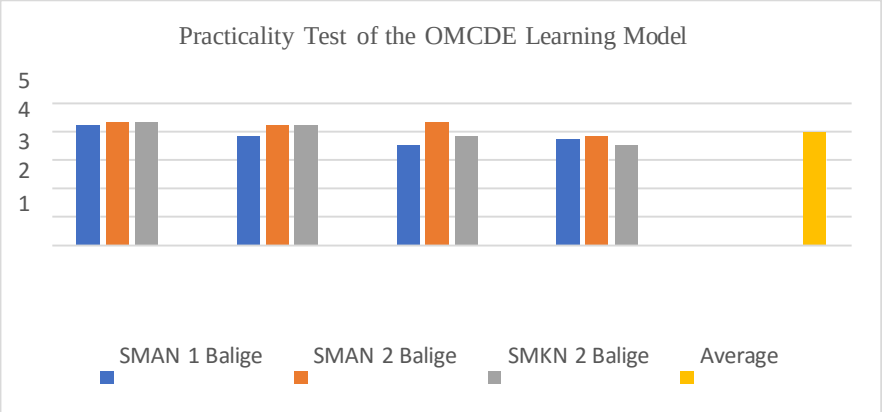

Figure 1.3 Bar Diagram of Practicality of the OMCDE Learning Model

25. Effectiveness of the OMCDE Learning Model

The pretest global competency of students taught using the Augmented Reality-based OMCDE learning model obtained the lowest score of 52 and the highest score of 78, the average score was 66.03 and the standard deviation was 7.23. The frequency distribution of students' pretest global competencies taught using the Augmented Reality-based OMCDE learning model can be seen in Figure 1.3 below:

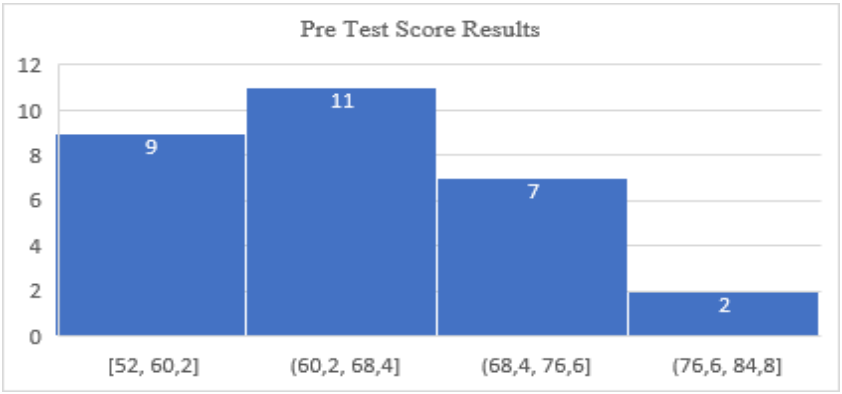

Figure 1.4 Bar Diagram of Pretest Score Results

The post-test global competency of students taught using the Augmented Reality-based OMCDE learning model obtained the lowest score of 65 and the highest score of 92, the average score was 80.52 and the standard deviation was 7.67. The frequency distribution of students' post-test global competencies taught using the Augmented Reality-based OMCDE learning model can be seen in Figure 1.3 below:

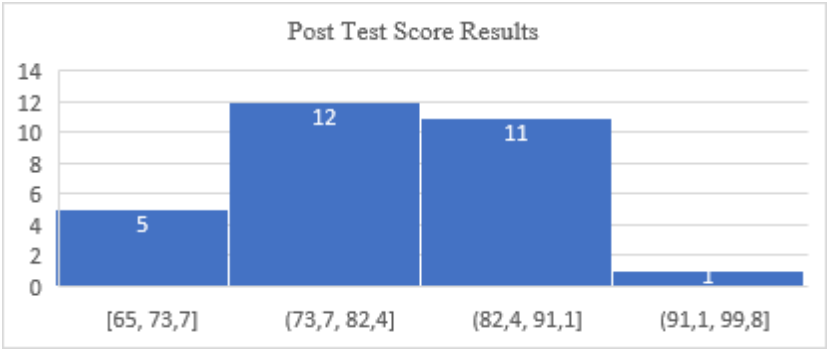

Figure 1.4 Bar Diagram of Posttest Score Results

Based on the results of research data processing, there are differences in the global competence of students who use the Augmented Reality-based OMCDE learning model. Based on the results of the t test, tcount =

2.16 while ttable = 1.67. Because tcount = 2 .16 > ttable = 1.67, it can be concluded that students' posttest global competence through the use of the Augmented Reality-based OMCDE learning model is higher than students' pretest global competence. This can be seen from the average posttest score (82.52) which is higher than the pretest score (66.03). This data proves that the OMCDE learning model based on Augmented Reality can improve students' global competence.

2.17

3. Conclusion

The OMCDE learning model based on Augmented Reality is stated to be good in terms of product and suitable for use to support student activity in learning at school; stated to be practically used to make it easier for teachers to carry out the teaching and learning process in schools; and declared effective in increasing students' global competence.

4. Discussion

There is much debate about what constitutes integrated STEM education and therefore there is also disagreement about how to most effectively approach instruction when integrating STEM domains [24];[25]. For the purposes of this systematic literature review, we examined STEM projects that involve interdisciplinary or transdisciplinary integration of at least two domains [26]. Interdisciplinary integration involves connecting closely related concepts and skills from two or more scientific disciplines with the aim of deepening knowledge and skills [27]. Transdisciplinary integration applies knowledge and skills from two or more disciplines to real-world problems and projects forming a learning experience [28].

Global competence requires various skills that a person must master, so it is hoped that education can prepare students to master these various skills in order to become successful individuals in life. Important skills in the 21st century are still relevant to the four pillars of life which include learning to know, learning to do, learning to be and learning to live together. This framework of thought is still considered relevant to current educational interests and can be developed according to the needs of the 21st century [28]. Each of these four principles contains specific skills that need to be empowered in learning activities, such as critical thinking skills, problem solving, metacognition, communication skills, collaboration, innovation and creatio n, information literacy, and various other skills.

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Corresponding Author: Efendi Napitupulu, Lecturer at the Faculty of Engineering, Medan State University.

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