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EFFECTS OF AUGMENTED REALITY INTEGRATION (ARI) BASED MODEL PHYSICS INDEPENDENT LEARNING (MPIL) FOR FACILITATING 21ST-CENTURY SKILLS (21-CS)

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Abstract

Augmented Reality (AR) based learning provides real experiences for educators and new strategies for presenting physics concepts but also provides opportunities for students to interact interactively, spontaneously, and interestingly. Previous research has shown that AR has many advantages in education, but only a few focus on Independent Learning, such as freedom in problem solving and independent learning skills in physics learning. This study develops an Augmented Reality Integration (ARI) learning application based on the Physics Independent Learning (MPIL) model on the marine physics concept. This application is to explore the influence of ARI on 21st-Century Skills (21-CS) which consists of Critical Thinking, Collaboration, Communication, and Creativity. A Quasi-Experimental Method was used, and 88 students aged 20-22 were randomly assigned to the experimental and control groups. After an intervention for 3 weeks, it was found that integrating ARI technology into physics learning can (1) significantly increase students' Creativity Thinking and Critical Thinking on Marine physics concepts; (2) guiding students to further improve in Communication, and Collaboration in solving problems contained in the ARI application; and (3) stimulate students' learning motivation to be enthusiastic about learning physics concepts.

Keywords – Augmented Reality Integration (ARI), Physics Independent Learning Model (MPIL), 21st-Century Skills (21-CS).

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1. Introduction

The rapid development of science and technology provides significant changes to the development of the learning process (Duan, Edwards & Dwivedi, 2019). The rapid development of science and technology encourages educators to innovate in learning, one of which is the use of learning media as an effort to improve the quality of education (Supriyatno, Susilawati & Ahdi, 2020). The current paradigm of physics education has changed and metamorphosed from a simple shift in knowledge, which is given and received in learning by imitating experimental physics concepts to creating an environment for students to actively participate in the process of scientific investigation and acquire knowledge independently (Chung, Hwang & Lai, 2019).

The of pedagogic content, marine physics is one of the more challenging topics in the implementation of normal learning (García de la Vega, 2021). Several factors cause it because there are concepts in marine physics that are too difficult to visualize because the concepts of marine physics consist of temperature, light, hydrostatic pressure, and waves (Brewin, Sathyendranath, Platt, Bouman, Ciavatta, Dall'Olmo et al., 2021). These concepts are abstract for students to understand, in addition, when introducing marine physics concepts, lecturers will usually do many demonstrations in class about marine physics concepts through videos, most of which require complicated and difficult to obtain laboratory tools and equipment, so they are often difficult to use in class for various practical reasons (Gamage, Wijesuriya, Ekanayake, Rennie, Lambert & Gunawardhana, 2020).

Nevertheless, some of the available computer software and virtual experimental environments have not been able to provide new opportunities for educators and students for learning (Kamińska, Sapiński, Wiak, Tikk, Haamer, Avots et al., 2019). Currently emerging technology that can combine real objects and virtual objects with a real outside environment in real-time which is currently known as Augmented Reality (AR) (Santi, Ceruti, Liverani & Osti, 2021). AR is a technology that combines two-dimensional and or three-dimensional virtual objects into a real three-dimensional environment and then projects these virtual objects in real time (Hamzah, Rizal & Simatupang, 2021). AR applications in education that have been researched and developed so far include SMART, Virtuoso, Protein Magic Book, AlienContact, ARex, The Table Mystery, AR Physics, Tinkerlamp, Tapacarp, and Kaleidescope (Prior, 2018). All these studies have positive results related to increased collaboration, deeper understanding, and student motivation when using AR-based learning media. The advantage of AR is that it has attractive visuals, because it can display 3D objects that were previously abstract as if they exist in a real environment, such as electromagnetic induction material (Tuli & Mantri, 2020). In addition, AR can turn abstract material into interactive knowledge, and present abstract knowledge as visible, audible, and understandable (Cai, Liu, Wang, Liu & Liang, 2021).

A good understanding of physics concepts should be carried out comprehensively and practice 21st century skills. These skills consist of those consisting of Creativity Thinking, Critical Thinking, Communication, and Collaboration are necessary to increase the competitiveness of graduates (Supena, Darmuki & Hariyadi, 2021). The use of AR techniques for physics experiments, especially to produce experimental devices for convex lens image formation, can stimulate student interest in learning and increase activity levels (Kencana, Iswanto & Wibowo, 2021). The AR technology can enhance digital literacy, creative thinking, communication, collaboration, and problem-solving skills, which are 21st century skills, which are required to transform information rather than simply receive it (Papanastasiou, Drigas, Skianis, Lytras & Papanastasiou, 2019). AR has many advantages for learning, including facilitating learning, concretizing abstract concepts, increasing mastery of concepts, improving laboratory skills, improving problem solving, and improving critical thinking skills (Akcayir, Akcayir, Pektas & Ocak, 2016; Abdusselam & Karal, 2020; Radu & Schneider, 2019; Fidan & Tuncel, 2019).

The maximize AR implementation, an appropriate method approach is needed, the right learning is the Physics Independent Learning Model (Pandiangan, Sanjaya & Jatmiko, 2017). This learning model is an innovative science model that can encourage everyone to solve problems and teach the stages of problem solving to think critically and have independence where in physics learning, individual transitions in the thinking process must be ensured at each stage of problem solving (Ulger, 2018). The development of MPIL uses a scientific approach with methods of investigation, assignment, collaboration, discussion, and presentation so that it can bridge the gap between the competency expectations of graduates and the conditions in the field according to the demands of the 21st Century Skills.

However, AR has been developed a lot, but what is able to train 21st-Century Skills (21-CS) based on the Physics Independent Learning Model has not been widely developed. Whereas 21-CS is very important in training students to be ready to face the demands of the era of disruption. The importance of mastering

21st century skills is because at this time students are required to be able to develop life skills and soft skills, including the ability to think critically and solve problems, creativity, communicate, and collaborate. This study designed an Augmented Reality Integration (ARI) based Model Physics Independent Learning (MPIL) for Facilitating 21st-Century Skills (21-CS).

1.1. Augmented Reality (AR)

Many people think that AR is an evolution of Virtual Reality (VR), now I am clear that AR and VR are two technologies with different research and development paths and uses. AR integrates digital information with the real environment in which humans live. Everything is processed and produced in real time (Ahmad & Jibril, 2021). This is one of the main differences with virtual reality, which uses an artificial environment. AR uses the real world and complements it with digital information. Essentially, it increases the amount of information humans can extract from the environment (Boboc, Duguleană, Voinea, Postelnicu, Popovici & Carrozzino, 2019). Technological developments are now no longer limited to certain areas, but they influence and reinforce each other. AR is one of these innovative technologies (Papanastasiou et al., 2019). Augmented Reality is a technique of rendering virtual objects on real images captured by the camera and has the advantage of providing a different sense of reality from virtual reality. Especially in the field of physics can provide a more realistic expression through various physics-based simulations that allow students to achieve high achievements (Yıldırım & Baran, 2021).

Research that discusses AR including AR devices and examines its effects in learning Physics, the produced an AR-based magnetic field learning application that was able to emphasize natural interactions. Then an exploration was carried out to determine the effect of the application on natural interactions in physics learning and deep understanding compared to traditional learning tools (Thees, Kapp, Strzys, Beil, Lukowicz & Kuhn, 2020; Sirakaya & Sirakaya, 2020; Muali, Setyosari, Purnomo & Yuliati, 2020). The analysis of the results shows that the application can improve learning attitudes and learning outcomes. The weakness of this application is that the system is not always stable, the animations produced overlap each other (Abdusselam & Karal, 2020). The produced Magnetism AR, a magnetism teaching material using AR and sensing technology (Radu & Schneider, 2019). Then carried out an exploration of its effect on academic achievement and student learning processes, and to identify students views on AR. Furthermore, The AR application called FenAR which contains 36 different applications. Then carried out an exploration of the effect of Problem Based Learning (PBL) assisted by Augmented Reality (AR), namely FenAR on learning achievement and attitudes towards physics subjects (Fidan & Tuncel, 2019).

1.2. Physics Independent Learning Model (MPIL)

MPIL is an innovative science learning model that can encourage everyone to solve problems and teach the stages of problem solving to think critically and have independence where in physics learning, individual transitions in the thinking process must be ensured at each stage of problem solving (Pandiangan et al., 2017). MPIL development uses a scientific approach with methods of investigation, assignment, collaboration, discussion, and presentation so as to bridge the gap between the competency expectations of graduates and the situation on the ground according to the demands of the 21st century and the curriculum for implementing the Indonesian National Qualifications Framework (KKNI)26 and the National Higher Education Standards (KKNI)26 SNPT)8 applicable in Indonesia. So, the complete syntax of the Physics Independent Learning Model (MPIL) is shown in Figure 1.

Based on Figure 1. it is obtained information that the MPIL syntax applied in this study is a learning model consisting of six phases: (1) Initiation and Persistence, (2) Responsibility, (3) Self and Group Investigation, (4) Analysis, (5) Presenting and Discussion (6) Strengthening and Evaluation. The main purpose of this developed model is to improve problem solving skills and independent learning skills of students. The learning model designed is expected so that students have high independence in problem solving activities (Hasibuan, Saragih & Amry, 2019).

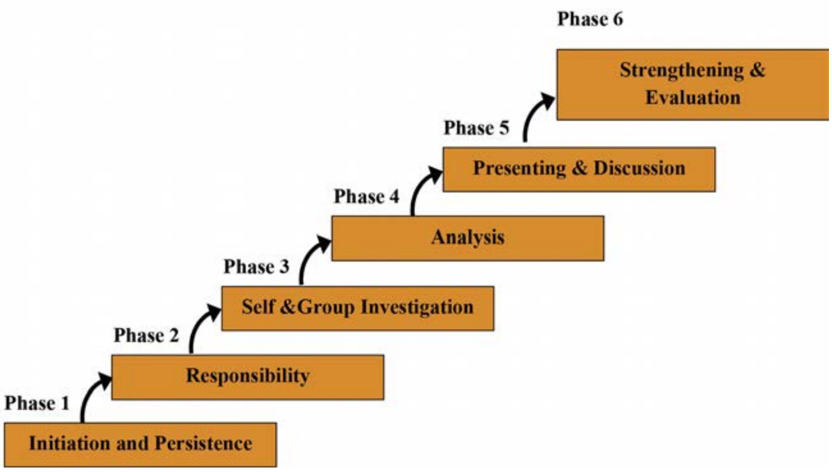

Figure 1. Model of Physics Independent Learning (MPIL) Phase

1.3. 21st-Century Skills (21-CS)

21-CS of research involving the ability to use software or operate digital devices, also emphasizes cognitive and socio-emotional skills to perform tasks and solve problems in the environment (González-Pérez & Ramírez-Montoya, 2022; Boyaci & Atalay, 2016). This 21-CS distinguishes three intersecting dimensions namely the technical, cognitive, and socio-emotional dimensions of digital literacy (Güneş & Bahçivan, 2018). Overall, digital literacy is presented as a mindset that allows users to perform intuitively in a digital environment, and to both easily and effectively access the wide range of knowledge embedded in that environment. Various conceptualizations of digital skills, accounting for technical and substantial aspects or content aspects of skills, more specifically operational, formal, information, communication, content creation, and strategic skills (Van Deursen & Mossberger, 2018). The proposed definition eschews the technological point of view by accounting for the technical and content-related aspects provided by the Internet. Finally, the concept of 21-CS focuses on the question of what organizations should do with ICT. 21-CS is the ability to develop and use ICTs to participate adequately in an environment increasingly dominated by access to electronically supported information, and a well-developed ability to synthesize this information into effective and relevant knowledge 21-CS in research shown in Figure 2.

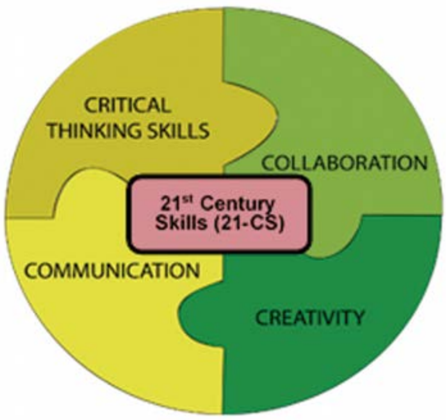

Figure 2. 21st-Century Skills (21-CS)

Based on Figure 2. it can be concluded that the 21st-Century Skills (21-CS) measured in this study are 4C (Communication, Collaboration, Critical Thinking, Creativity) (Erdoğan, 2019). The results of previous studies show that, one can easily generalize the existing literature to focus more on optimizing AR technology in improving 21st century skills (Papanastasiou et al., 2019) and rarely AR research explores the mechanism behind AR technology for this (Wang, Ong & Nee, 2018). Motivated by such observations in the field today, this study attempts to examine the impact of Augmented Reality Integration (ARI) based Model Physics Independent Learning (MPIL) for Facilitating 21st-Century Skills (21-CS) applied in physics education and attempts to reveal the underlying causes of the phenomena that may occur. Thus, the research question posed in this study is whether the 21st-Century Skills of students with the Physics Independent Learning Model change during the learning process by applying ARI.

2. Methodology

2.1. Experimental Tools

The research study of researchers developed Augmented Reality Integration (ARI) based Model Physics Independent Learning (MPIL) for Facilitating 21st-Century Skills (21-CS), an experimental marine physics AR application to be explored by the experimental group, while the control group used demonstrations using simulation-based Flash for the same concept.

2.2. Augmented Reality Integration (ARI)

There are two experiments in ARI. Experiment 1 provides a macroscopic overview of the concept of measuring light in Marine waters in marine physics, as shown in Figure 1a. In ordinary classrooms or laboratories, due to unfavourable light source control and Secchi Disk accuracy. However, this tool is not optimal in measuring light transparency in waters. ARI enables this phenomenon to be demonstrated by providing ideal light control and accurate monitoring of water brightness, this is shown in Figure 3a. Experiment 2 shows the view of waves working in terms of physics concepts. It is often used to analyses the dynamic behaviour of the movement of waves in the Marine, but we do not know the process by which it occurs, this is shown in Figure 3b.

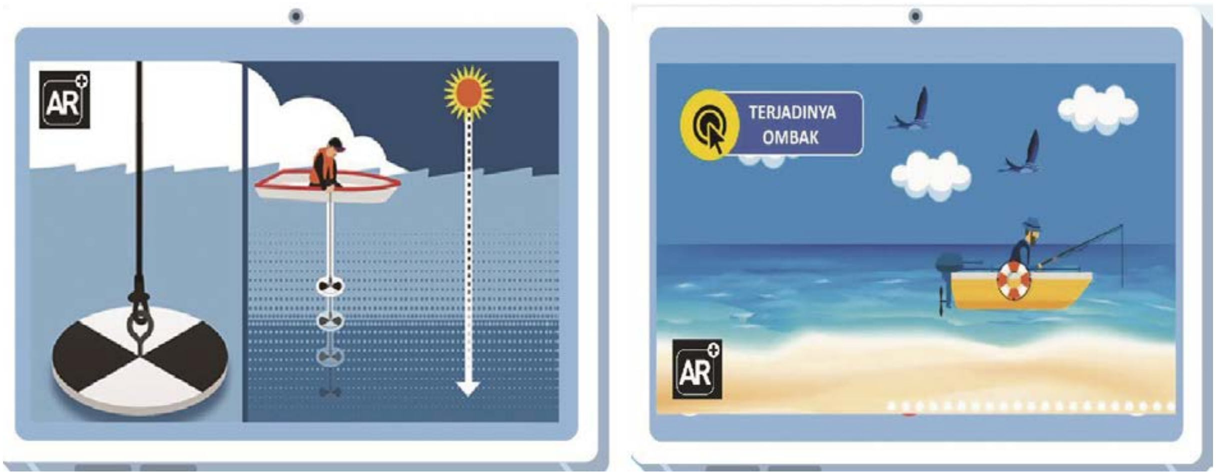

Figure 3. Screenshots of experiments in the ARI on the measurement of the of light and waves

Learning using AR was created in an environment that is Model Physics Independent Learning, the researchers used Vuforia, a development software, to build a highly realistic exploratory environment that supports natural interactions through programming in the Unity 3D environment. To differentiate Unity 3D from Flash simulations and other applications, the 3D models used by ARI do not magnify features but restore them with high precision and natural interaction between students. Students press a special area on the card to control their own lab equipment in ARI. In addition, the natural interaction method returns the control method in the real environment, so that the student's virtual experimental experience can be applied to real life. The initial appearance of ARI on the concept of marine physics is shown in Figure 4.

Figure 4. Screenshot of the marine physics concept ARI application

Figure 5. Natural interactions of the Secchi Disk resizing application

In addition, students can change the size of the Secchi Disk by moving the slider on their smartphone, as shown in Figure 4. Implementation of ARI learning by promoting MPIL in the physics learning process. In each experiment, the researchers provided the relevant laboratory equipment virtually and actualized the function of the equipment through the initiation and persistence stages, responsibility, self-group investigation, analysis, presentation and discussion, and the final stage of strengthening and evaluation. Using ARI can create more experimental opportunities for students and can further enrich students' practical experience. Students gain practical experience is closely related to a positive learning experience. In addition, from macroscopic to microscopic levels, from natural marine phenomena to theoretical applications, ARI can encourage students to acquire additional knowledge, inspire discovery and exploration, apply knowledge, and promote sequential and logical understanding of material so that they actively internalize it to a more meaningful understanding.

2.3. Instrument

The measurement instrument used in this study consists of a Critical Thinking, Collaboration, Communication, and Creativity test about optical phenomena. In this ARI study, the test of 21st-Century Skills (21-CS) consists of Creative Thinking Skills (CreTS), Critical Thinking Skills (CriTS), Communication Skills (ComS), Collaboration Skills (ColS) on ARI which is used as a data collection tool.

2.4. Creative Thinking Skills (CreTS) Test

This creativity skills test is based on a test developed by the researcher himself that has been validated by an expert. The test consists of 5 essay questions with a reliability coefficient of 0.72, either category. This test question is based on the Creativity indicator and core competencies from the concept of the atomic core structure according to the curriculum. Creativity indicators used in the research are asking questions, guessing the causes, guessing the consequences of an event, improving the output (Wechsler, Saiz, Rivas, Vendramini, Almeida, Mundim et al., 2018).

2.5. Critical Thinking Skills (CriTS) Test

The Critical Thinking Skills test is based on tests developed by researchers themselves that have been validated by experts. The test consists of 5 description questions with a reliability coefficient of 0.78 good category. These test questions are based on Critical Thinking indicators and core competencies of the concept of atomic core structure according to the curriculum. Critical Thinking Indicators used in the research are formulating problems, analyzing arguments, asking, and answering questions, evaluating, and defining (Wechsler et al., 2018).

2.6. Collaboration Skills (ColS) Test

This collaboration skills test is based on a test developed by the researcher himself that has been validated by an expert. The test consists of 5 description questions with a reliability coefficient of 0.70 good category. This test question is based on the Collaboration Indicator used in this study, namely the skills to work together, synergize with each other, adapt in various roles and responsibilities, and respect differences of opinion when learning using ARI (Blau, Shamir-Inbal & Hadad, 2020).

2.7. Communication Skills (ComS)

This communication skills test is based on tests developed by the researchers themselves which have been validated by experts. This test consists of 5 description questions with a reliability coefficient of 0.68 good category. This test question is based on Indicator Communication, namely listening skills, writing skills, oral skills that occur during learning using ARI (Claro, Salinas, Cabello-Hutt, San Martín, Preiss, Valenzuela et al., 2018).

2.8. Experimental Sample

The study used a sample of students from two experimental and control classes which were selected as research objects. A total of 88 students aged 20-22 were randomly assigned to the experimental and control groups, each with 44 students, The sample comes from one of the universities in Indonesia. Both groups of students completed the experiment with the ARI application with the help of the lecturer and filled out the same experimental report. Before the experiment, the two groups of students studied concepts related to marine physics, which consisted of the concepts of measuring the transparency of light and waves. The results of the pre-test showed that there was no significant difference in their performance in learning physics in 21st Century Skills.

2.9. Procedure

The experimental design for this study is shown in Figure 6. After the purpose of this experiment was introduced, all subjects were asked to fill out a pre-test to analyses their level of Critical Thinking, Collaboration, Communication, and Creativity. After an intervention for 3 weeks, it was found that integrating ARI technology into physics learning can (1) significantly increase students' Creativity Thinking and Critical Thinking on Marine physics concepts; (2) guiding students to further improve in Communication, and Collaboration in solving problems contained in the ARI application; and (3) stimulate students' learning motivation to be enthusiastic about learning physics concepts.

The experimental intervention was initiated after the completion of the pre-test, lasting for 3 weeks and one lesson per week, as shown in Figure 7. Both classes were taught by the same teacher, as experimental guidance and assistance was provided when needed. During this period, the two groups of students were asked to complete the MPIL stages, namely the initiation and persistence stages, responsibility, self-group investigation, analysis, presentation and discussion, and the last stage of strengthening and evaluation. During the whole intervention process, except for the different teaching tools (Flash and AR simulation) used, textbooks, other tools, and materials. used by the two groups of students are the same. The final stage of the intervention was carried out to all students who were asked to fill out the post-test.

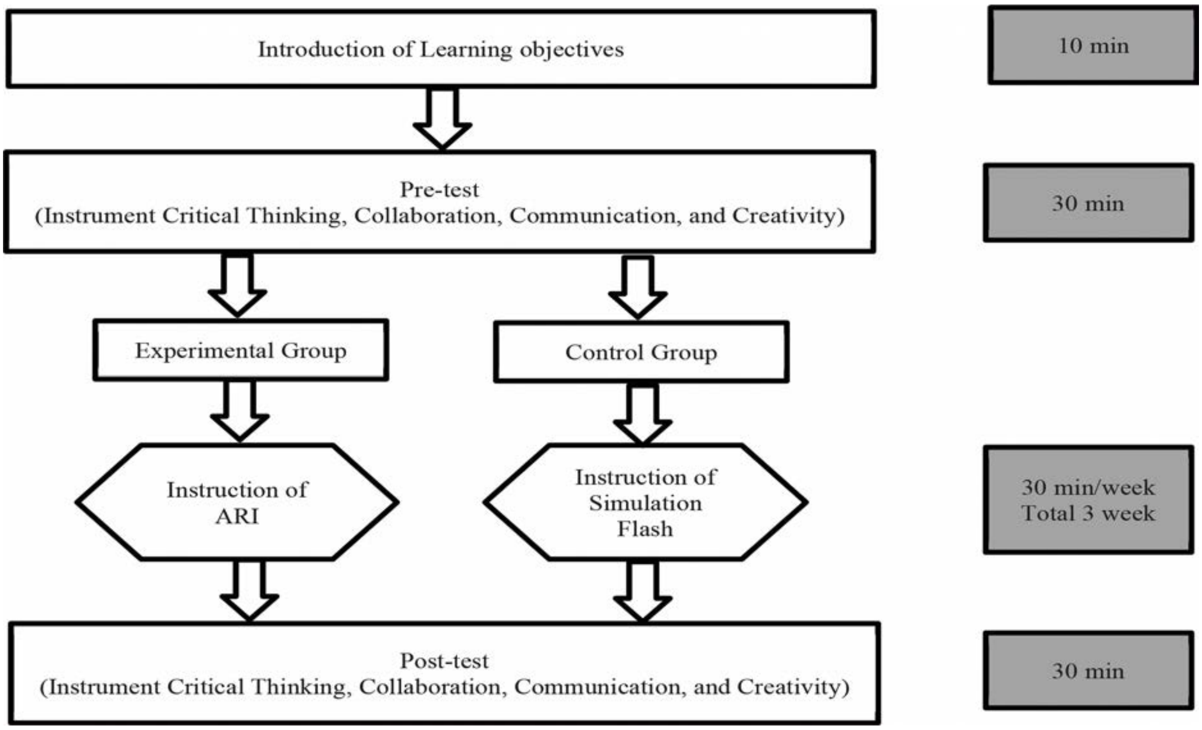

Figure 6. Experimental Research Procedure

Figure 7. Students of ARI experiments

3. Result and Discussion

3.1. Compare 21st-CS Based MPIL ARI and Simulation Flash Groups

Comparison of 21st century (21-CS) skills consisting of Critical Thinking, Collaboration, Communication, and Creativity with MPIL in the AR and Flash Simulation group as shown in Figure 6. To find out whether ARI technology affects 21-CS students towards physics learning, then were given a 21-CS instrument and a questionnaire to ask for responses from both groups before and after the lesson. Before the intervention, no significant difference ($p>0.01$) was found between the two groups, as shown in Table 1.

Based on Figure 8. Information is obtained that students are enthusiastic about learning to use ARI. Learning marine physics interactively and interestingly will make it easy for students to master physics concepts. If microscopic concepts are easy to understand, macroscopic concepts can be understood. The results of the 21st-Century Skills student data with the Physics Independent Learning Model change during the learning process by applying ARI are shown in Table 1.

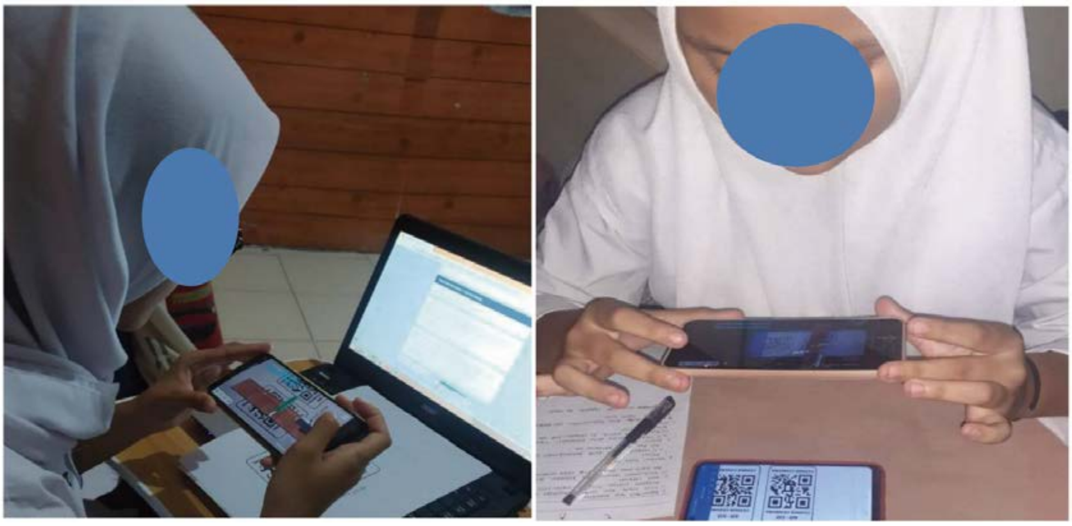

Figure 8. Students of MPIL learning

21-CS Component	Group	Before treatment		t-test	
		Mean	**SD**	**T**	**p**
CreTS	ARI	10.57	1.31	1.65	.11
	Simulation Flash	10	1.85		
CriTS	ARI	10.65	1.35	1.72	.12
	Simulation Flash	10.08	1.95		
ComS	ARI	10.47	1.29	1.58	.10
	Simulation Flash	10.1	1.97		
ColS	ARI	10.55	1.3	1.69	.13
	Simulation Flash	10.2	1.88		

Note: Grup ARI $n = 44$; Simulation Flash group $n = 44$, Creative Thinking Skills (CreTS), Critical Thinking Skills (CriTS), Communication Skills (ComS), Collaboration Skils (ColS).

Table 1. T-test scores in 21st-CS of the control and experimental group pre-test

The average value and standard deviation of 21st-Century Skills (21-CS) consists of Creative Thinking Skills (CreTS), Critical Thinking Skills (CriTS), Communication Skills (ComS), Collaboration Skills (ColS) marine physics learning from the two groups before and after teaching intervention are shown in Table 2. Univariate analysis of covariance (ANCOVA) was used to explore the differences in 21-CS marine physics learning between the two. group of students after the intervention. The covariate was the 21-CS level before the learning intervention. The dependent variable was 21-CS after the teaching intervention. At the same time, Table 2 also shows the adjusted mean and variance of the two groups after implementation.

21-CS Component	Group	Before treatment		After treatment		Univariate ANCOVA			
		Mean	SD	Mean	SD	Mean	Standard error	F	n^2
CreTS	ARI	10.57	1.31	19.55	2.93	20.5	0.64	.58	.45
	Simulation Flash	10	1.85	18.59	3.07	19.54	0.64		
CriTS	ARI	10.65	1.35	20.05	3.09	21	0.66	.61	.47
	Simulation Flash	10.08	1.95	19.39	3.12	20.34	0.66		
ComS	ARI	10.47	1.29	19.89	3.13	20.84	0.65	.60	.46
	Simulation Flash	10.1	1.97	18.9	3.17	19.85	0.65		
ColS	ARI	10.55	1.3	20.35	3.23	21.3	0.68	.61	.49
	Simulation Flash	10.2	1.88	19.99	3.11	20.94	0.68		

Note: Grup ARI n = 44; Simulation Flash group n = 44, Creative Thinking Skills (CreTS), Critical Thinking Skills (CriTS), Communication Skills (ComS), Collaboration Skils (ColS).
$^*p$, <.05; ** p, <.01

Table 2. Descriptive statistics of students' pre-test and post-test scores on the ARI based on MPIL with ANCOVA summary

The results of the ANCOVA analysis showed that students in the MPIL-based ARI group achieved a significantly higher 21-CS physics learning score compared to the Flash Simulation group. For example, Creative Thinking Skills (CreTS) (F= 0.58, p < 0.01, n2= 0.45), Critical Thinking Skills (CriTS), (F= 0.61, p < 0.01, n2= 0.47), Critical Thinking Skills (CriTS), (F= 0.61, p < 0.01, n2= 0.47), Communication Skills (ComS), (F= 0.60, p < 0.01, n2= 0.46), and Collaboration Skills (ColS) (F= 0.61, p < 0.01, n2= 0.49) The results show that the ARI Based MPIL into the marine physics learning environment can improve 21 st century skills, especially in terms of Creative Thinking Skills (CreTS), Critical Thinking Skills (CriTS), Communication Skills (ComS), and Collaboration Skills (ColS) students.

The positive aspect of applying ARI for learning marine physics is that these AR can be accessed and shared with anyone to try this ARI in developing an understanding of the concept of measuring the transparency of light in water and working waves in terms of physics concepts. However, some students stated that they could not fully express their thoughts because the understanding that was built from this microscopic concept light did facilitate thinking skills, but the completion of this media took a relatively long time. A summary of student views is given below: *"… this ARI contributed significantly to my interest in learning physics concepts, which at first, I didn't like physics. Likewise, my understanding of completing mission after mission in this ARI trains me to think creatively and critically because to go to the next mission, I must complete a task in the form of a question. This issue is a challenge for me. This causes me to take a relatively long time to think."*

In addition, some expressed negative aspects of ARI based MPIL, namely internet access in areas, especially areas far from urban areas, so that internet signal is very difficult, so this AR is less than optimal. Many researchers have developed AR learning platforms that can be used in education as a means for student engagement in learning activities (Chang & Hwang, 2018). Because learning to use AR helps students to be able to participate in learning activities from anywhere and navigate in virtual learning spaces (Scavarelli, Arya & Teather, 2021). Virtual learning can overcome the barriers of distance, time, and location, to be able to meet and interact (Lassoued, Alhendawi & Bashitialshaaer, 2020). In addition, AR for learning has a positive impact on constructivism concepts and provides experiences to students. argue that learning using AR can facilitate student-cantered constructivist learning and make learning more flexible and provide an interesting learning experience (Hsu, 2021). Learning AR can form conceptual thinking and abstract the real environment (Elsayed & Al-Najrani, (2021). Students demonstrate that learning to use AR provides a learning experience in the role of an authentic designer and provides an immersive challenge.

The increase in 21-CS students due to the implementation of MPIL-based ARI is because this ARI is equipped with a marine physics report module as a place to scan from AR. This report module has three main sections, namely the opening section, the core section, and the closing section. In the opening section of the enrichment book, there are several components, namely (1) the front cover of the module, (2) the Francis page, (3) the copyright page of the module, (4) the introduction page, (5) the instructions for using the module, (6) a list content, and (7) concept maps. In the core part of the report module, there are several components, namely (1) front cover of each chapter, (2) concept map, (3) materials, and (4) summary. In the closing section of the report module, there are several components, namely (1) evaluation questions in the form of multiple choices accompanied by reasons, (2) crossword puzzle games, (3) a glossary containing foreign terms contained in the enrichment book.

The results obtained by this study are in line with other studies, AR can significantly improve student learning outcomes and AR applications have enormous potential and many benefits for teaching and learning environments (Wibowo, Nasbey, Sanjaya, Darman, Ahmad & Ismail, 2021). AR has the potential to engage, stimulate and motivate students to explore material in the classroom from different angles. AR is effective in teaching students about electromagnetic material compared to ordinary books. The motion-sensing AR application helps students understand the material of magnetic fields and magnetic induction. In addition, these devices can increase the motivation and interest of students, as well as encourage students to learn more actively. In this study, it has similarities with the research that the researchers did, namely on the technique of developing AR-based learning media.

The use of AR allows users to learn microscopic physics concepts and communication interfaces in one dimension based on text into a 3D environment colourful, and immersive (Chen, Zhang, Wu & Chen, 2020). Students enjoy learning in this ARI user because students like to use the visual world in 3D space and socialize. This AR encourages interaction between students in connecting people from various parts of the world with 3D virtual technology (Lamb, Lin & Firestone, 2020). Overall, AR provides a virtual environment to create a shared experience for students and teachers to work collaboratively together and demonstrate instruction. However, there are several barriers and challenges to the adoption of AR for learning. These obstacles include (1) lack of explanation in learning because it only uses interactive; (2) students do not focus on learning because they always hold their Smartphone; (3) lack of interaction between students and teachers.

4. Conclusions

AR has a positive impact on students' interest in learning, communication, critical thinking skills and increasing activity levels (Akcayir at al., 2016; Abdusselam & Karal, 2020). However, only a few of them are researchers on the mechanics of Marineic physics concepts to measure their impact on students on 21st century skills (21-CS). In this study, 21-CS was chosen as a key measure to explain how AR can have a positive effect in the educational context of marine physics courses. currently exploring the effect of AR technology on 21-CS physics students at a public university in Indonesia by setting up a control experiment. Meaningful results were found in response to both research questions. In the case of 21-CS, the use of ARI technology can significantly improve 21-CS students in marine physics learning. The current study found that students in the ARI scored significantly higher than the Flash Simulation group in terms of 21 Century Skills. The 21-CS enhancement does make sense because AR's cognitive effects enhance digital literacy, creative thinking, collaboration, and problem-solving skills, which are 21st century skills, which are required to transform information rather than simply receive it (Papanastasiou et al., 2019). AR has many advantages for learning, including facilitating learning, concretizing abstract concepts, increasing mastery of concepts, improving laboratory skills, improving problem solving, and improving (Radu & Schneider, 2019; Fidan & Tuncel, 2019).

In brief, this research develops MPIL-based ARI learning media and applies it in marine physics education. The experimental results show that ARI-assisted experiments can significantly improve 21-CS students in marine physics learning; they can direct students to concentrate more on higher-level conceptions of physics learning than on lower-level conceptions. For further research on the application of ARI to physics, application design and learning activities should pay more attention to the microscopic conception of physics that trains students' high order thinking skills. One lesson from the results of this study is that AR should be designed for (1) Initiation and Persistence, (2) Responsibility, (3) Self and

Group Investigation, (4) Analysis, (5) Presenting and Discussion, and (6) Strengthening and Evaluation. This stage is called the MPIL stage. So that with AR equipped with MPIL learning, it will sharpen students' understanding of 21st century concepts and skills.

However, the limitations of the application in this study were also found, on the one hand, the technology could be improved in this study. Several suggestions from students made suggestions for further improvement using ARI in learning scenarios. Some students suggested that the critical thinking skills test be in the form of a description so that students need a long time to answer the question, especially questions on indicators of interpretation, self-regulation, and explanation. So, it is necessary to test the three indicators of Critical Left Skills. Two students said, "When you touch the smartphone to the module by hand, sometimes the AR marker is not sensitive. So, they had to remove it and put it back on." This is because the AR button interaction is based on natural optical technology and the stability of the software interaction should be further improved.

Declaration of Conflicting Interests

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References

Abdusselam, M.S., & Karal, H. (2020). The effect of using augmented reality and sensing technology to teach magnetism in high school physics. *Technology, Pedagogy and Education*, 29(4), 407-424. https://doi.org/10.1080/1475939X.2020.1766550

Ahmad, S.A., & Jibril, S. (2021). Augmented Reality for Augmenting Education. *Contemporary Journal of Education and Development*, 1(2), 10-21.

Akçayır, M., Akçayır, G., Pektaş, H.M., & Ocak, M.A. (2016). Augmented reality in science laboratories: The effects of augmented reality on university students' laboratory skills and attitudes toward science laboratories. *Computers in Human Behavior*, 57, 334-342. https://doi.org/10.1016/j.chb.2015.12.054

Blau, I., Shamir-Inbal, T., & Hadad, S. (2020). Digital collaborative learning in elementary and middle schools as a function of individualistic and collectivistic culture: The role of ICT coordinators' leadership experience, students' collaboration skills, and sustainability. *Journal of computer assisted learning*, 36(5), 672-687. https://doi.org/10.1111/jcal.12436

Boboc, R.G., Duguleană, M., Voinea, G.D., Postelnicu, C.C., Popovici, D.M., & Carrozzino, M. (2019). Mobile augmented reality for cultural heritage: Following the footsteps of Ovid among different locations in Europe. *Sustainability*, 11(4), 1167. https://doi.org/10.3390/su11041167

Boyaci, S., & Atalay, N. (2016). A Scale Development for 21st Century Skills of Primary School Students: A Validity and Reliability Study. *International Journal of Instruction*, 9(1), 133-148. https://doi.org/10.12973/iji.2016.9111a

Brewin, R.J., Sathyendranath, S., Platt, T., Bouman, H., Ciavatta, S., Dall'Olmo, G. et al. (2021). Sensing the ocean biological carbon pump from space: A review of capabilities, concepts, research gaps and future developments. *Earth-Science Reviews*, 217, 103604. https://doi.org/10.1016/j.earscirev.2021.103604

Cai, S., Liu, C., Wang, T., Liu, E., & Liang, J.C. (2021). Effects of learning physics using Augmented Reality on students' self-efficacy and conceptions of learning. *British Journal of Educational Technology*, 52(1), 235-251. https://doi.org/10.1111/bjet.13020

Chang, S.C., & Hwang, G.J. (2018). Impacts of an augmented reality-based flipped learning guiding approach on students' scientific project performance and perceptions. *Computers & Education*, 125, 226-239. https://doi.org/10.1016/j.compedu.2018.06.007

Chen, M., Zhang, P., Wu, Z., & Chen, X. (2020). A multichannel human-swarm robot interaction system in augmented reality. *Virtual Reality & Intelligent Hardware*, 2(6), 518-533. https://doi.org/10.1016/j.vrih.2020.05.006

Chung, C.J., Hwang, G.J., & Lai, C.L. (2019). A review of experimental mobile learning research in 2010–2016 based on the activity theory framework. *Computers & education*, 129, 1-13. https://doi.org/10.1016/j.compedu.2018.10.010

Claro, M., Salinas, Á., Cabello-Hutt, T., San Martín, E., Preiss, D.D., Valenzuela, S. et al. (2018). Teaching in a Digital Environment (TIDE): Defining and measuring teachers' capacity to develop students' digital information and communication skills. *Computers & Education*, 121, 162-174. https://doi.org/10.1016/j.compedu.2018.03.001

Duan, Y., Edwards, J.S., & Dwivedi, Y.K. (2019). Artificial intelligence for decision making in the era of Big Data–evolution, challenges and research agenda. *International Journal of Information Management*, 48, 63-71. https://doi.org/10.1016/j.ijinfomgt.2019.01.021

Elsayed, S.A., & Al-Najrani, H.I. (2021). Effectiveness of the augmented reality on improving the visual thinking in mathematics and academic motivation for middle school students. *EURASIA Journal of Mathematics, Science and Technology Education*, 17(8), em1991. https://doi.org/10.29333/ejmste/11069

Erdoğan, V. (2019). Integrating 4C skills of 21st century into 4 language skills in EFL classes. *International Journal of Education and Research*, 7(11), 113-124.

Fidan, M., & Tuncel, M. (2019). Integrating augmented reality into problem-based learning: The effects on learning achievement and attitude in physics education. *Computers & Education*, 142, 103635. https://doi.org/10.1016/j.compedu.2019.103635

Gamage, K.A., Wijesuriya, D.I., Ekanayake, S.Y., Rennie, A.E., Lambert, C.G., & Gunawardhana, N. (2020). Online delivery of teaching and laboratory practices: continuity of university programmes during COVID-19 pandemic. *Education Sciences*, 10(10), 291. https://doi.org/10.3390/educsci10100291

García de la Vega, A. (2021). Design-Based Implementation Research for Exploring the Ocean: A Geographical Perspective. In *Ocean Literacy: Understanding the Ocean* (115-147). Springer, Cham. https://doi.org/10.1007/978-3-030-70155-0_6

González-Pérez, L.I., & Ramírez-Montoya, M.S. (2022). Components of Education 4.0 in 21st century skills frameworks: systematic review. *Sustainability*, 14(3), 1493. https://doi.org/10.3390/su14031493

Güneş, E., & Bahçivan, E. (2018). A mixed research-based model for pre-service science teachers' digital literacy: Responses to "which beliefs" and "how and why they interact" questions. *Computers & Education*, 118, 96-106. https://doi.org/10.1016/j.compedu.2017.11.012

Hamzah, M.L., Rizal, F., & Simatupang, W. (2021). Development of Augmented Reality Application for Learning Computer Network Device. *International Journal of Interactive Mobile Technologies*, 15(12). https://doi.org/10.3991/ijim.v15i12.21993

Hasibuan, A.M., Saragih, S., & Amry, Z. (2019). Development of Learning Materials Based on Realistic Mathematics Education to Improve Problem Solving Ability and Student Learning Independence. *International electronic journal of mathematics education*, 14(1), 243-252. https://doi.org/10.29333/iejme/4000

Hsu, Y.C. (2021). Exploring the Effectiveness of Two Types of Virtual Reality Headsets for Teaching High School Mathematics. *EURASIA Journal of Mathematics, Science and Technology Education*, 17(8), em1986. https://doi.org/10.29333/ejmste/10996

Kamińska, D., Sapiński, T., Wiak, S., Tikk, T., Haamer, R.E., Avots, E. et al. (2019). Virtual reality and its applications in education: Survey. *Information*, 10(10), 318. https://doi.org/10.3390/info10100318

Kencana, H.P., Iswanto, B.H., & Wibowo, F.C. (2021). Augmented Reality Geometrical Optics (AR-GiOs) for Physics Learning in High Schools. In *Journal of Physics: Conference Series*, 2019(1), 012004. IOP Publishing. https://doi.org/10.1088/1742-6596/2019/1/012004

Lamb, R., Lin, J., & Firestone, J.B. (2020). Virtual reality laboratories: A way forward for schools?. *EURASIA Journal of Mathematics, Science and Technology Education*, 16(6), em1856. https://doi.org/10.29333/ejmste/8206

Lassoued, Z., Alhendawi, M., & Bashitialshaaer, R. (2020). An exploratory study of the obstacles for achieving quality in distance learning during the COVID-19 pandemic. *Education sciences*, 10(9), 232. https://doi.org/10.3390/educsci10090232

Muali, C., Setyosari, P., Purnomo, P., & Yuliati, L. (2020). Effects of Mobile Augmented Reality and Self-Regulated Learning on Students' Concept Understanding. *International Journal of Emerging Technologies in Learning (iJET)*, 15(22), 218-229. https://doi.org/10.3991/ijet.v15i22.16387

Pandiangan, P., Sanjaya, M., & Jatmiko, B. (2017). The validity and effectiveness of physics independent learning model to improve physics problem solving and self-directed learning skills of students in open and distance education systems. *Journal of Baltic Science Education*, 16(5), 651-665. https://doi.org/10.33225/jbse/17.16.651

Papanastasiou, G., Drigas, A., Skianis, C., Lytras, M., & Papanastasiou, E. (2019). Virtual and augmented reality effects on K-12, higher and tertiary education students' twenty-first century skills. *Virtual Reality*, 23(4), 425-436. https://doi.org/10.1007/s10055-018-0363-2

Prior, N. (2018). *Popular music, digital technology and society*. Sage. https://doi.org/10.4135/9781529714807

Radu, I., & Schneider, B. (2019). What can we learn from augmented reality (AR)? Benefits and drawbacks of AR for inquiry-based learning of physics. In *Proceedings of the 2019 CHI conference on human factors in computing systems* (1-12). https://doi.org/10.1145/3290605.3300774

Santi, G.M., Ceruti, A., Liverani, A., & Osti, F. (2021). Augmented reality in industry 4.0 and future innovation programs. *Technologies*, 9(2), 33. https://doi.org/10.3390/technologies9020033

Scavarelli, A., Arya, A., & Teather, R.J. (2021). Virtual reality and augmented reality in social learning spaces: a literature review. *Virtual Reality*, 25(1), 257-277. https://doi.org/10.1007/s10055-020-00444-8

Sırakaya, M., & Sırakaya, D.A. (2020). Augmented reality in STEM education: A systematic review. *Interactive Learning Environments*, 1-14. https://doi.org/10.1080/10494820.2020.1722713

Supena, I., Darmuki, A., & Hariyadi, A. (2021). The Influence of 4C (Constructive, Critical, Creativity, Collaborative) Learning Model on Students' Learning Outcomes. *International Journal of Instruction*, 14(3), 873-892. https://doi.org/10.29333/iji.2021.14351a

Supriyatno, T., Susilawati, S., & Ahdi, H. (2020). E-learning development in improving students' critical thinking ability. *Cypriot Journal of Educational Sciences*, 15(5), 1099-1106. https://doi.org/10.18844/cjes.v15i5.5154

Thees, M., Kapp, S., Strzys, M.P., Beil, F., Lukowicz, P., & Kuhn, J. (2020). Effects of augmented reality on learning and cognitive load in university physics laboratory courses. *Computers in Human Behavior*, 108, 106316. https://doi.org/10.1016/j.chb.2020.106316

Tuli, N., & Mantri, A. (2020). Experience Fleming's rule in electromagnetism using augmented reality: Analyzing impact on students learning. *Procedia Computer Science*, 172, 660-668. https://doi.org/10.1016/j.procs.2020.05.086

Ulger, K. (2018). The effect of problem-based learning on the creative thinking and critical thinking disposition of students in visual arts education. *Interdisciplinary Journal of Problem-Based Learning*, 12(1). https://doi.org/10.7771/1541-5015.1649

Van Deursen, A.J., & Mossberger, K. (2018). Anything for anyone? A new digital divide in internet-of-things skills. *Policy & internet*, 10(2), 122-140. https://doi.org/10.1002/poi3.171

Wang, Y., Ong, S.K., & Nee, A.Y.C. (2018). Enhancing mechanisms education through interaction with augmented reality simulation. *Computer Applications in Engineering Education*, 26(5), 1552-1564. https://doi.org/10.1002/cae.21951

Wechsler, S.M., Saiz, C., Rivas, S.F., Vendramini, C.M.M., Almeida, L.S., Mundim, M.C. et al. (2018). Creative and critical thinking: Independent or overlapping components? *Thinking Skills and Creativity*, 27, 114-122. https://doi.org/10.1016/j.tsc.2017.12.003

Wibowo, F.C., Nasbey, H., Sanjaya, L.A., Darman, D.R., Ahmad, N.J., & Ismail, H.N. (2021). The technology of interactive book Augmented reality (ibar) for facilitating Student 21-century skills. *Journal of Theoretical and Applied Information Technology,* 99(22), 6276-5286.

Yıldırım, Z., & Baran, M. (2021). A comparative analysis of the effect of physical activity games and digital games on 9th grade students' achievement in physics. *Education and Information Technologies*, 26(1), 543-563. https://doi.org/10.1007/s10639-020-10280-7

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