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THE TECHNOLOGY OF INTERACTIVE BOOK AUGMENTED REALITY (IBAR) FOR FACILITATING STUDENT 21-CENTURY SKILLS

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ABSTRACT

This study aims to development of technology Interactive Book Augmented Reality (IBAR) for Facilitating 21st-Century Skills (21-CS). Technology influences high school students towards learning, and to determine 21st-Century Skills (Critical Thinking, Collaboration, Communication, and Creativity) for AR applications. The research method used was a quasi-experimental design, in which one whole class was used in four schools in different cities. The total sample of the study was 120 students in grade 10 middle school students, the sample was randomly assigned to the experimental or control group. The experimental group completed the Interactive Book of the Atomic Nuclear Structure concept in their physics lesson using AR technology. Meanwhile the control group completed the same interactive book using traditional methods and textbooks. Students in the experimental group were found to have a higher level of achievement in 21st-Century Skills consisting of Critical Thinking, Collaboration, Communication, and Creativity compared to the control group. In addition, the results show that most students are challenged and want to continue to use AR applications in the future for learning. In addition, they also showed no signs of being afraid to study physics while using the IBAR.

Keywords: *Interactive Book Augmented Reality (IBAR), Facilitating Student, 21st-Century Skills (21-CS), Media in Education.*

1. INTRODUCTION

Science and technology are changing very rapidly so that they affect the social structure of society and affect human character. The adaptation process with changing human characters requires reform of the world of education because advances in science and technology in the educational environment are urgent [30] [24]. The urgency of this technological advancement demands the skills of 21st century humans [26]. This skill can be facilitated in learning because it is one of the main factors of concern. Learning is developed based on the skill categories of the 21st century globally, namely as follows: (a) ways of thinking: creativity and innovation, critical thinking, problem solving, decision making and learning to learn [32]; (b) ways to work: communicating and working together [4]; (c) tools for work: general knowledge and skills of information and communication technology (Aslan, 2015); (d) way to live: career, personal and social responsibilities including cultural awareness and competence [7]. In 21st century education involves aspects of skills and understanding that also involve

technology. Thus, innovation in learning is needed to meet the challenges in the 21st century.

In an era where the application of technology in everyday life that is contextual is increasing rapidly, the use of technology in education is becoming an important thing [25]. If a concept that is invisible to the eye or unobservable or a concept that is microscopic or abstract, students have difficulty understanding it [34]. So, to explain nature and natural phenomena that are unobservable during physics learning, a media tool is needed because to support classroom learning with technology it has become a necessity [6]. To deepen the students' learning environment, it is very important to facilitate them visually and intellectually through the application of technology, especially to explain microscopic and difficult concepts [38]. The application of technology will make it easier for students to perceive physical phenomena in concrete learning of physics. Educational technology in physics learning, serves to improve the quality of physics lessons through an effective scientific activity, developing Critical Thinking, Collaboration, Communication, and Creativity skills [29].

Augmented Reality (AR) technology is currently a trend and is starting to appear in the world of education. AR has recently begun to be used in schools as an interactive platform that displays a combination of virtual objects and the real world [2] [22]. The basic idea of AR is to improve human perception by embedding virtual components in real-world environments [13] [21]. AR can enhance the quality of traditional learning environments by displaying two (2D) or three-dimensional (3D) forms of representation, such as graphs, tables, and computer-generated graphics. animation, video, or text [31]. AR is two types of interactive technology and is registered in 3D and combines real and virtual objects [8]. When real-world images are taken with a camera, AR technology can point virtual objects to predetermined points in an image and translate the output through a specific program [36]. AR can invite students to think about visualizing abstract concepts in physics [16]. This media can also be used for students who have limited spatial intelligence, students are not able to translate or interpret a word or sentence easily, but the student is not said to be a stupid student. Imagination is the work of the right brain. The right brain is the center of human creativity. The right brain becomes the power center of the human mind because this is where everything is related to time and space such as intuition, imagination, and creativity [19]. AR is a promising immersive technology to reduce the challenges in studying physics [13]. AR provides many educational benefits [11] [12]. AR is a technology in the form of three-dimensional simulation or animation that can be developed into a learning method using a smartphone. AR in education can help students increase the amount of time they focus on the subject so that they can increase their level of achievement [35]. These things are very important in determining problems, especially problems that are not routine. Therefore, it is necessary to make learning that can explore the potential of the right brain, not only the potential of the left brain of students, because the human brain has the privilege of connecting sensory reality with information.

Some research on AR technology in learning includes the use of research question books to examine investigation activities in the laboratory [3]. AR to complement the traditional paper-based laboratory manual with additional virtual content (i.e., text, audio, video, animation, and simulation) describes how to prepare and conduct experiments, as well as some of the underlying phenomena [17]. AR has been used as a medium to increase student motivation, understanding and engagement with the content being studied [14]. AR as an effective tool in learning technology makes it possible to interact with objects that belong to the virtual or real world, to learn through experimentation, participation, and interactivity, to increase the motivation and attention of students. Learning becomes more fun and effective, even when it comes to exploring and knowing abstract concepts or complex phenomena, and this is thanks to the visualization and realization possibilities of concepts accessible to AR technology [23].

In this condition, the learning situation is like during the current Covid-19 pandemic, learning cannot be done face-to-face, teachers and lecturers are learning with an online system [20]. Many applications are used in online learning, one of which is through video conferencing. Virtual-based learning is difficult to see the active condition of the students, especially because of the network or signal reasons. Monitoring and parental support are needed so that distance learning runs smoothly. In addition, learning devices such as laptops, tabs or smartphone is now widely used by students in online learning, so that the use of smartphones can be used as a medium for student learning in other ways through AR technology.

AR technology has indeed been developed by several other researchers, the application of AR in courses is fun, reduces cognitive load, increases

motivation [18] and interest in the course, increases the opportunity to ask questions, increases interaction between students, new opportunities for individual learning, concretize abstract concepts [16]. So that physics learning emphasizes on providing direct experience to develop the competence of students' abilities so that they can explore and know the nature of the universe scientifically. In addition, not many researchers have studied AR technology to facilitate 21st century skills [15] [27] [10]. However, the AR that has been developed by these researchers has not been much working on AR technology on the concepts of microscopic and unobservable physics. If this microscopic physical phenomenon can be applied in the form of AR technology, it will be more meaningful. In addition, the challenges in studying physics today require new ideas that can support students' interest in studying physics.

The Justify research contribution in the form of the technology Augmented Reality in the form of Interactive Book Augmented Reality (IBAR) This is significant because it will have a positive impact in the world of educational technology, because the topics discussed are becoming a trend and will be of interest to Augmented reality that trains 21st century skills (Critical Thinking, Collaboration, Communication, and Creativity). In addition, IBAR can explain the physical concept of the topic of the structure of the atomic nucleus which is microscopic in size and unobservable into a real visualization so that students can understand this concept easily.

In addition, although various scientific research themes have been discussed about the impact of AR on learning, the concept of Atomic Core Structure has not been studied in detail. Therefore, the study has the aim of filling in the gaps in the literature. The main objective of this study is to determine the impact of Interactive Book Augmented Reality (IBAR) for Facilitating 21st-Century Skills (21-CS). In line with the purpose of this study, the research hypothesis was built as follows: (1) Students in the experimental group who studied using IBAR experienced an increase in 21st Century Skills (21-CS): Critical Thinking, Collaboration, Communication, and Creativity higher than the control group. (2) Student responses in the experimental group who learned to use IBAR were higher than the control group.

2. METHOD

2.1. Research Model

The research conducted is based on quantitative research methods with a quasi-experimental design. A quasi-experimental design was selected and adopted in a case where the experimental and control groups were not formed randomly, but instead formed with existing classes [28]. With this design, the experimental and control groups are compared with each other based on pretest scores to determine whether the group has a level of 21st-Century Skills (21-CS): Critical Thinking, Collaboration, Communication, and Creativity. If the levels of Critical Thinking, Collaboration, Communication, and Creativity are the same in the two groups, one of the classes is selected to become the experimental group that participates in the intervention program.

In this study, students in the experimental and control groups used one whole class at four schools in different cities. The total sample of the study was 120 students in grade 10 middle school students, the samples were randomly assigned to either the experimental or control groups. The experimental group completed the Interactive Book of the Atomic Nuclear Structure concept and afterward their physics learning using AR technology. Meanwhile the control group completed the same interactive book using traditional methods and textbooks. This is necessary due to the limited number of classes (one for each) in each class in the district where this study was conducted. The mean scores of students in previous physics classes were taken as pretest scores, which were compared using the independent sample t-test method. This analysis showed that there was no significant difference in the mean scores for the control group (M=78.00, SD=24.63) and the experimental group (M=78.38 & SD = 25.48), t (199) =.675.

The two groups took physics subjects on the concept of the Atomic Nuclear Structure which is a unit in the matter of the Atomic Nucleus and Radioactivity. Meanwhile, the expected competence is that students can understand the characteristics of atoms and their use in everyday life. Meanwhile, the experimental group completed this concept with AR technology in the form of an interactive book. Meanwhile, the control group completed this concept using traditional textbook learning methods. To see the impact of IBAR (interactive Book Augmented Reality) evaluation was carried out in the experimental group and to control the achievement of 21st-Century Skills (21-CS): Critical Thinking, Collaboration, Communication, and Creativity. This 21-CS achievement uses previously validated Critical Thinking, Collaboration, Communication, and Creativity test instruments. In addition, to evaluate students' responses to the application of IBAR technology to the concept of Core Structure, a questionnaire containing questions in the

experimental group was used in the application of IBAR. All the tools used in data collection, application in learning and implementation in this study is shown in Figure 1.

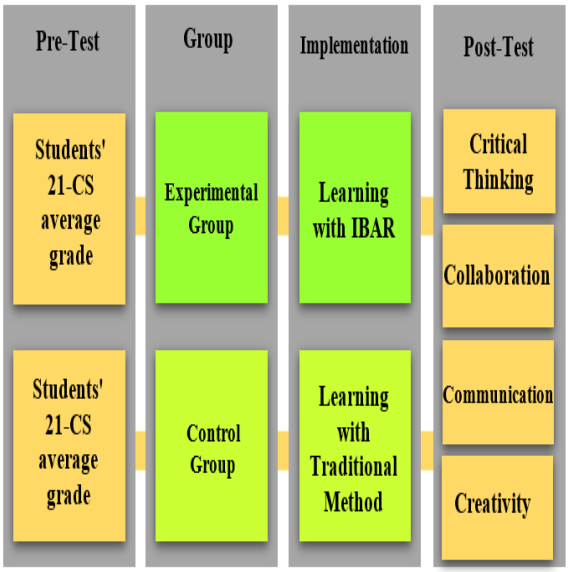


Figure 1. The research method in the application of IBAR

2.2. Sample

The research sample in this study totaled 120 10th grade students aged between 16 and 17 years from four schools from different cities. Students have never seen or used AR technology before. The demographic characteristics of the research sample are as shown in Table 1.

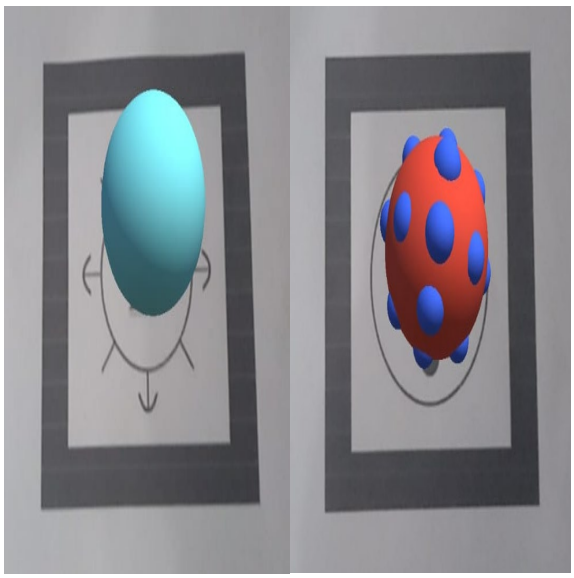
Table 1. Demographic characteristics of the sample

Group	Experimental Group	Control Group	Total
Boy	25	25	50
Girl	35	35	70
Total	**60**	**60**	**120**

In this IBAR study, purposive sampling was used. This method allows researchers to gain speed and ease of access to samples. In addition, it allows the researcher to obtain a large sample size. This sampling method is preferred because the selected schools are willing to participate in this research. The four schools were chosen because based on the results of the school final exam scores in physics courses, the average results were almost the same, so it was possible that the sample would be normally distributed and homogeneously. In addition, these four schools have facilities to facilitate the application of AR technology. In this context, the four schools, each school is represented by a sample of 30 so the total is 120 students. The total sample of the Experimental Group and Control Group each amounted to 60 students.

The IBAR design for the experimental group, on the concept of the "Atomic Nuclear Structure" concept was chosen because the concept of the atomic nucleus is a microscopic concept because the very small size of the atomic nucleus makes it difficult for students to understand it. Due to its unobservable nature, the concept of the atomic nucleus structure has the potential to attract students' attention and attract student learning. In addition, this concept includes abstract concepts and there is no other way to realize these concepts in real schools. This has led to a decrease in asking students to learn the concept of the atomic nucleus structure over time so that it has an impact on the development of 21st century skills of students or has a negative impact on academic achievement. As the object of the problem, the concept of the structure of the atomic nucleus is difficult to understand and requires students to use their imagination and think abstractly, so teaching must be concreted to make it more interesting. IBAR-based learning is designed and developed by an expert with a degree in Physics Education, especially learning media. This material is arranged in the form of an interactive book (IBAR) with activities consisting of a total of 4 activities. This IBAR contains activities containing scannable AR simulations and consists of several concepts of the structure of the atomic nucleus. The concept of the atomic nucleus structure developed in this research equipped with AR is the concept of Dalton's Atom, Thompson's Atom, Rutherford's Atom and Bohr's Atom.

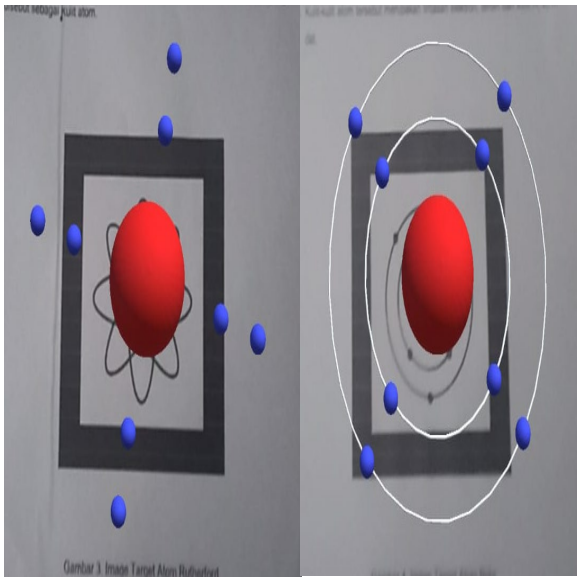
The implementation of IBAR in the experimental group was carried out at two weeks (8 hours). IBAR was taught to the experimental group through an interactive book based on AR, while the control group used traditional methods using physics textbooks on the structure of the atomic nucleus. In the experimental group, the concept was taught by the teacher with AR-based IBAR, where students actively participate in the class and each student can use the IBAR in every activity. During classroom learning, the virtual objects of the AR-based IBAR use the students' own smartphones, thus creating a learning environment that facilitates the construction of the atomic nucleus structure concept. The procedures applied during the implementation phase and visuals for the implementation of IBAR are shown in Figure 2 and Figure 3.



(a) The result of moving Image Dalton's Atom *(b) The result of moving Image Atom Thompson*

Figure 2. Results of moving images of Dalton and Thompson's Atom

In the first week of the meeting, students were given lessons about introduction to the concept of atomic nucleus structure using IBAR on the concept of Atom Dalton and Atom Thompson. Students obtain information about learning materials prepared with IBAR technology.



(a) The result of moving Image Rutherford's Atom *(b) The result of moving Image Atom Bohr*

Fig. 3. Results of moving images of Rutherford's and Bohr Atom

The second week, Characteristics of the Rutherford Atom, and the Bohr Atom, teaches students how the Rutherford Atom and the Bohr Atom work and how their nuclei move.

2.3. Data Collection

In this IBAR study, the 21st-Century Skills test consists of Critical Thinking, Collaboration, Communication, and Creativity on AR which is used as a data collection tool.

2.3.1. Critical Thinking Test

The Critical Thinking 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 is 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 [33]. In the process of developing the Critical Thinking test, preparation, preparation, and validation of the content by experts are reviewed by two physics teachers and an academic who is an expert in the development of the Critical Thinking test instrument. The reliability of this Critical Thinking test can be trusted because the content has been validated by 3 experts.

2.3.2. Collaboration Test

This collaboration 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 is 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 IBAR.

2.3.3. Communication Test

This communication 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 is good category. This test question is based on Indicator Communication, namely listening skills, writing skills, oral skills that occur during learning using IBAR.

2.3.4. Creativity Test

This Creativity test is based on a test developed by the researcher himself that has been validated by an expert. The test consisted 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 [33]. In the process of developing this Creativity test, the preparation, creation, and validation of content from experts is reviewed by two physics teachers and an academician who is an expert in developing the Creativity test instrument. The reliability of this Critical Thinking test can be trusted because it has been validated by 3 experts.

2.3.5. Student Response to IBAR

In this study, students' responses to AR were evaluated using an instrument developed [23]. This response instrument consists of 15 items that reflect 3 factors: satisfaction, anxiety, and willingness. Satisfaction relates to students' thinking about whether AR technology is easy to use and useful for learning. Willingness to show students' desire to use technology in the future. If the level of student satisfaction and willingness is high, then the attitude towards AR technology will also be positive. Anxiety relates to doubts about the use of AR technology. When anxiety levels are high, students' attitudes are negatively affected. This scale is rated on a 5-Point-Likert scale, ranging from 5 (Strongly Agree) to 1 (Strongly Disagree) and has an internal reliability coefficient of 0.78. The highest score is 80 and the lowest score on the scale is 25 and.

2.4. Data Analysis

The data analysis of this research was carried out by means of descriptive analysis by identifying outliers of data that were less good and extreme data being deleted. Furthermore, the slope of the courthouse was controlled for each variable, and it was obtained that the data was normally distributed because the value was between -1 and +1. Next, an independent t-test was conducted to determine group differences. In addition, Pearson's correlation analysis was carried out to test the correlation between the variables as it confirms the normal distribution assumption.

3. RESULTS AND DISCUSSION

The results of this study have a scope on 21st-Century Skills (21-CS): Critical Thinking, Collaboration, Communication, and Creativity and student responses to the application of IBAR technology to the concept of Core Structure. Detailed information about 21-CS and student responses to the application of IBAR technology of the experimental and control groups can be seen in Table 2.

Table 2. 21-CS data and student responses to the application of IBAR technology in the Experiment and Control Group

	21-CS		Student Response to IBAR	
	Experimental Group	Control Group	Experimental Group	Control Group
N	56	55	56	55
M	85,73	71,53	89,73	69,33
SD	7.75	16,93	8.185	14,71

Based on Table 2, information is obtained that it is shown that students in the experimental group have higher Critical Thinking, Collaboration, Communication, and Creativity compared to the control group (M = 85.73 & SD = 7.75) and Student Response to IBAR in the experimental group higher than the control group (M = 89.73 & SD = 14.71).

The significant difference in 21st-Century Skills (21-CS): Critical Thinking, Collaboration, Communication, and Creativity between students who use IBAR experimental group and control group. In determining the significant difference between students in the experimental group and the control group in terms of 21-CS, an independent sample t-test was carried out and the results are presented in Table 3.

Table 3. Students' 21-CS Data Differences on the application of IBAR technology in the Experiment and Control Group

	21-CS	
	Experimental Group	Control Group
M	85,73	71,53
SD	7.75	16,93
t	6,46	3,82
p	0,00	0,00

Based on Table 3, information is obtained that there are significant differences at the level of Critical Thinking, Collaboration, Communication, and Creativity between students using the IBAR application in the experimental group better than the control group using traditional methods (t = 6.46, p <0 ,05). So that students who learn to use IBAR technology have a higher level of 21-CS compared to students in the control group.

The students' responses to the application of IBAR technology to the Core Structure concept. In determining student responses to the application of IBAR technology to the concept of the Core Structure, descriptive statistics were used to identify

the attitudes of the experimental group towards IBAR. The full results are shown in Table 4.

Table 4. Responses of experimental group students to the application of IBAR technology

	Factor of student Response to IBAR		
	Use satisfaction	Use willingness	Use anxiety
Min.	4.21	2.45	1,53
Max.	5.00	5.00	4.77
M	4.67	4.91	1,67
SD	0,57	0,77	0,73

Based on Table 4, it is found that students like to use the IBAR application (M = 4.67 & SD = 0.57) and students are willing to use IBAR again (M = 4.91 & SD = 0.77). Meanwhile, these students also did not show anxiety using the IBAR application (M = 1.67 & SD = 0.73).

The purpose of this study was to determine the impact of Interactive Book Augmented Reality (IBAR) for Facilitating 21st-Century Skills (21-CS). This technology affects high school students towards learning, and to determine 21st-Century Skills (Critical Thinking, Collaboration, Communication, and Creativity) for AR applications. In addition, another objective of this study is to investigate students' responses to the application of IBAR technology to the Atomic Core Structure concept. Information was obtained that student in the experimental group had a higher level of 21st-Century Skills Critical Thinking, Collaboration, Communication, and Creativity towards IBAR Implementation compared to the control group. This significant difference in experimental group results can be used as evidence of the positive effect of IBAR technology. IBAR in the concept of Atomic Core Structure is one of the topics covered in physics learning, developed, and applied in the experimental group because for students this concept is microscopic and unobservable. In addition, because most of them contain abstract concepts, students generally have difficulty learning relevant concepts and succeed in achieving meaningful learning.

The IBAR application provides benefits for students to show the phenomenon of the structure of the atomic nucleus which was originally an abstract concept that is physically visualized through 3D virtual objects. This 3D phenomenon facilitates students to understand the concept in depth and more meaningful learning and has an increased impact on 21st-Century Skills in the group compared to the control group. The results showed a significant difference between the experimental and control groups in improving the Critical Thinking, Collaboration, Communication, and Creativity of students who took physics learning with IBAR technology compared to students who learned through traditional methods. The results of this study are in accordance with the relevant literature among others [1] [4] [5] [27]. AR has a positive impact so that learning is more challenging in physics education [9]. AR provides an interesting experience for students [35]. Based on the literature, it is stated that if new technology is used in education, it can attract students' interest and increase motivation towards learning [9]. Thus, students become active during the learning process and facilitate understanding of physics concepts [1] [16]. Strengthened again, if AR technology can provide magic because it reflects the appearance of objects on a piece of paper [37]. In addition, AR can enhance the user's sensory perception of the real world by dynamically applying virtual elements to the physical environment.

The development of AR is very fast because it is widely used in the world of education, such as advertising, medicine, defense, military, and tourism which are growing rapidly from year to year. This brings a new dimension to the world of education and facilitates students with interactive and interesting learning experiences and teaching processes through AR real-life experiences in physics laboratories [3]. Thus, AR has an impact on flexibility in learning from and being able to provide a debriefing to students about 21st century skills [10] [16]. Unlike other educational technology, media applications, AR offers students a fun, engaging, enthusiastic and immersive learning environment.

Meanwhile, AR also has drawbacks such as excessive cognitive load in multiple tasks, difficult design to manufacture, low sensibility. However, if AR is designed validly, it can strengthen real-world contexts and facilitate learning [18]. The transformation of objects in AR media is extraordinary for students in forming students' attitudes [22]. It may also contribute to the achievement and facilitate 21st century skills for students. In addition, AR complements traditional paper-based laboratory manuals with additional virtual content (i.e., text, audio, video, animation, and simulation) explaining how to set up and conduct experiments, as well as some of the underlying phenomena [17]. AR has been used as a medium to increase student motivation, understanding and engagement with the content being studied [14]. AR as an effective tool in learning of technology makes it possible to interact with objects that belong to the virtual or real world, to learn through

experimentation, participation, and interactivity, to increase the motivation and attention of students. Learning becomes more fun and effective, even when it comes to exploring and knowing abstract concepts or complex phenomena, and this is thanks to the visualization and realization possibilities of concepts accessible to AR technology [23].

AR applications offer students an extraordinary experience, and thus, facilitate the development of positive attitude development. This is in accordance with previous research. AR is an interactive platform that displays a combination of virtual objects and the real world [2] [22]. The basic idea of AR is to improve human perception by embedding virtual components in real-world environments [13] [21]. AR can enhance the quality of traditional learning environments by displaying two (2D) or three-dimensional (3D) forms of representation, such as graphs, tables, and computer-generated graphics. animation, video, or text [31]. AR is two types of interactive technology and is registered in 3D and combines real and virtual objects [8]. When real-world images are taken with a camera, AR technology can point virtual objects to predetermined points in an image and translate the output through a specific program [36].

Based on the research results, students in the experimental group have higher Critical Thinking, Collaboration, Communication, and Creativity compared to the control group. Also, the Student Response to IBAR in the experimental group was higher than the control group. This is in accordance with the statistical tests carried out, namely there are significant differences at the level of Critical Thinking, Collaboration, Communication, and Creativity between students using the IBAR application in the experimental group better than the control group using traditional methods. In addition, from the student response data to IBAR that students are willing to use IBAR again and these students also do not show anxiety. This is in line with the benefits of AR being able to invite students to think about visualizing abstract concepts in physics [16]. This media can also be used for students who have limited spatial intelligence, students are not able to translate or interpret a word or sentence easily, but the student is not said to be a stupid student. Imagination is the work of the right brain. The right brain is the center of human creativity. The right brain becomes the power center of the human mind because this is where everything is related to time and space such as intuition, imagination, and creativity [19].

4. CONCLUSIONS

This paper provides an overview of the Interactive Book Augmented Reality (IBAR) for Facilitating Student 21st-Century Skills (21-CS). Aspects of 21-CS consisting of Critical Thinking, Collaboration, Communication, and Creativity show positive results after learning physics using AR applications. IBAR is applied to four schools in different cities and to high school students in grade 10. The results showed that students in the experimental group had higher Critical Thinking, Collaboration, Communication, and Creativity compared to the control group. In addition, Student Response to IBAR in the experimental group was higher than the control group. Based on students' responses to IBAR, it was concluded that students were willing to use IBAR again in physics learning and these students also did not show anxiety about the implementation of IBAR learning.

Finally, the correlation between Critical Thinking, Collaboration, Communication, and Creativity in the experimental group and the control group shows that there is a significant difference in levels between students using the IBAR application compared to groups using traditional methods. No other significant correlation was obtained. Thus, it can be concluded that the Interactive Book Augmented Reality (IBAR) for Facilitating 21st-Century Skills (21-CS) has a positive impact, especially the concept of the structure of the atomic nucleus which is microscopic in size. Based on the findings of this study, the following suggestions can be given.

- IBAR Physics Learning contributes positively to students' Critical Thinking, Collaboration, Communication, and Creativity.
- This research is limited to the concept that is microscopic or abstract and unobservable. To realize and visualize concepts that are not abstract, further studies need to be carried out to prove it.
- IBAR technology used to teach the concept of the structure of the atomic nucleus can improve 21st century skills. Using AR to teach other concepts in science is an opportunity that can be optimized and useful.
- This research was conducted with grade 10 students, so that similar studies can be carried out on students with different classes.

Discussion on limitations based on the data and suggestions from this study is that this research is limited to concepts that are microscopic or abstract and cannot be observed. So, to realize and visualize

concepts that are not abstract, further research needs to be done to test them. In addition, appropriate strategies are needed to be used by teachers in optimizing distance learning using IBAR. The learning media used is the use of the IBAR application which is considered suitable for students. The supporting factors in this learning are the competence of professional teachers and the ability of students to operate learning devices, both smartphone and laptops. While the inhibiting factors are students' diverse cognitive abilities, unfamiliar with distance learning models, internet stability barriers, insufficient internet quota, and parents who are less intensive in assisting students in learning. Other findings in this study are the need for students to adapt, intensive assistance from parents, and increasing teacher competence in supporting the implementation of the distance learning process.

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REFRENCES:

[1] Abdüsselam, M. S. (2014). Teachers' and Students' Views on Using Augmented Reality Environments in Physics Education: 11th Grade Magnetism Topic Example. *Pegem Journal of Education & Instruction,* 4(1), 59-74.

[2] Akçayır, M., & Akçayır, G. (2017). Advantages and challenges associated with augmented reality for education: A systematic review of the literature. *Educational Research Review*, 20, 1–11. doi:10.1016/j.edurev.2016.11.002

[3] Akçayir, M., Akçayir, G., Pektas, 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.

[4] Ananiadou, K., & Claro, M. (2009). 21st-century skills and competences for new millennium learners in OECD countries. *Organisation for Economic Co-operation and Development*.

[5] Aslan, S. (2015). Is learning by teaching effective in gaining 21st-century skills? The views of pre-service science teachers. *Educational Sciences: Theory & Practice,* 15(6), 1441–1457.

[6] Astra, I.M., Wibowo, F.C., Susanti, D., Darman, D. R. (2020). Massive Open Online Simulation (MOOS) of physics concepts microscopic for improving creative thinking. *Journal of Physics: Conference Series* 1869 (1), 012181.

[7] Bedir, H. (2019). Pre-service ELT teachers' beliefs and perceptions on 21st-century learning and innovation skills (4Cs). Journal of Language and Linguistic Studies, 15(1), 231–246.

[8] Caboni, F., & Hagberg, J. (2019). Augmented reality in retailing: a review of features, applications and value. *International Journal of Retail & Distribution Management*, 47(11), 1125–1140. doi:10.1108/ijrdm-12-2018-0263

[9] Cai, S., Chiang, F.-K., Yuchen-Sun, Y., Lin, C., & Lee, J. J. (2017). Applications of augmented reality-based natural interactive learning in magneticfield instruction. *Interactive Learning Environments,* 25(6), 778–791. https://doi.org/10.1080/10494820.2016.1181094

[10] [10] Chen, C., Yang, C., Huang, K., & Yao, K. (2020). Augmented reality and competition in robotics education: Effects on 21st century competencies, group collaboration and learning motivation. *Journal of Computer Assisted Learning*. doi:10.1111/jcal.12469

[11] Chen, M.-P., Wang, L.-C., Zou, D., Lin, S.-Y., Xie, H., & Tsai, C.-C. (2020). Effects of captions and English proficiency on learning effectiveness, motivation and attitude in augmented-reality-enhanced theme-based contextualized EFL learning. Computer Assisted Language Learning, 1-31.

[12] Cheng, K. H., & Tsai, C. C. (2020). Students' motivational beliefs and strategies, perceived immersion and attitudes towards science learning with immersive virtual reality: A Partial least squares analysis. *British Journal of Educational Technology,* 51(6), 2139-2158.

[13] Cheng, K.-H., & Tsai, C.-C. (2012). Affordances of Augmented Reality in Science Learning: Suggestions for Future Research. *Journal of Science Education and Technology*, 22(4), 449–462. doi:10.1007/s10956-012-9405-9

[14] Coimbra, Cardoso, & Mateus. (2015). Augmented Reality: An Enhancer for Higher

Education Students in Math's Learning. *Procedia Computer Science.* 67, 332-339

[15] Craciun, D., & Bunoiu, M, (2016). Augmented Reality In Romanian Science Education Pros And Cons. The International Scientific Conference eLearning and Software for Education; *Bucharest*, 3, (1). DOI:10.12753/2066-026X-16-205

[16] Faridi, H., Tuli, N., Mantri, A., Singh, G., & Gargrish, S. (2020). A framework utilizing augmented reality to improve critical thinking ability and learning gain of the students in Physics. *Computer Applications in Engineering Education.* doi:10.1002/cae.22342

[17] Frank, J. A., & Kapila, V. (2017). Mixed-reality learning environments: Integrating mobile interfaces with laboratory test-beds. *Computers & Education,* 110, 88–104.

[18] Georgiou, Y., & Kyza, E. A. (2018). Relations between student motivation, immersion and learning outcomes in location-based augmented reality settings. *Computers in Human Behavior*, 89, 173–181. doi:10.1016/j.chb.2018.08.011

[19] Hu, X.S. et al., (2019). Feasibility of a real-time clinical augmented reality and artificial intelli-gence framework for pain detection and localization from the brain. *J. Med. Internet Res.* 21 (6), e13594.

[20] Huei-Chuan Wei & Chien Chou (2020). Online learning performanceand satisfaction: do perceptions and readiness matter?, *Distance Education,* 41:1, 48-69 DOI:10.1080/01587919.2020.1724768

[21] Ibáñez, M.-B., & Delgado-Kloos, C. (2018). Augmented reality for STEM learning: A systematic review. *Computers & Education*, 123, 109–123. doi:10.1016/j.compedu.2018.05.002

[22] İbili, E. & Şahin, S. (2015). Investigation of the effects of augmented reality usage on students' attitudes towards computer and their perception of computer self-efficacy in teaching Geometry. *Necatibey Faculty of Education Journal of Electronics, Science and Mathematics* (EFMED) 9(1), 332-350.

[23] Küçük, S., Yilmaz, R.M., Baydaş, Ö. ve Göktaş, Y. (2014). Augmented Reality Applications Attitude Scale in Secondary Schools: Validity and Reliability Study. *Education and Science*, 39(176), 383-392.

[24] Liu, Q., Cheng, Z., & Chen, M. (2019). Effects of environmental education on environmental ethics and literacy based on virtual reality technology. *The Electronic Library*, 37(5) 860-877.

[25] Naik, G., Chitre, C., Bhalla, M. y Rajan, J. (2020). Impact of use of technology on student learning outcomes: evidence from a large-scale experiment in India. *World Development*, 127.

[26] O'Neal, L. J., Gibson, P., & Cotten, S. R. (2017). Elementary School Teachers' Beliefs about the Role of Technology in 21st-Century Teaching and Learning. *Computers in the Schools*, 34(3), 192–206. doi:10.1080/07380569.2017.1347443

[27] Papanastasiou, G., Drigas, A., Skianis, C., Lytras, M., & Papanastasiou, E. (2018). Virtual and augmented reality effects on K-12, higher and tertiary education students' twenty-first century skills. *Virtual Reality*. doi:10.1007/s10055-018-0363-2

[28] Reichardt, C. S. (2019). *Methodology in the social sciences. Quasi-experimentation: A guide to design and analysis.* The Guilford Press.

[29] Sahin, D., & Yilmaz, R. M. (2019). The effect of Augmented Reality Technology on middle school students' achievements and attitudes towards science education. *Computers & Education,* 103710. doi:10.1016/j.compedu.2019.103710

[30] Semarkhanova, E.K., Bakhtiyarova, L.N., Krupoderova, E.P., Krupoderova, K.R., Ponachugin, A.V. (2018). Information technologies as a factor in the formation of the educational environment of a university. In: *Advances in Intelligent Systems and Computing*, 622, 179–186

[31] Thees, M., Kapp, S., Lukowicz, P., & Kuhn, J. (2019). Smartglasses as assistive tools for higher science education: Towards a descriptive model of AR-based science laboratories. In J. Bastiaens (Ed.), *Proceedings of EdMedia þinnovate learning* (pp. 53–62). Amsterdam, Netherlands: Association for the Advancement of Computing in Education (AACE).

[32] Valtonen, T.,Hoang, N., Sointu, E., Naykki, P., Virtanen, A.,Sanna, J., Kati, M., & Johanna, P., Kukkonen, J. (2021). How preservice teachers perceive their 21st-century skills and dispositions: Alongitudinal perspective. *Computers in Human Behavior*.

116(3), 1–9. https://doi.org/10.1016/j.chb.2020.106643

[33] Wechsler, S. M., Saiz, C., Rivas, S. F., Vendramini, C. M. M., Almeida, L. S., Mundim, M. C., & Franco, A. (2018). Creative and critical thinking: Independent or overlapping components? *Thinking Skills and Creativity*, 27, 114–122. doi:10.1016/j.tsc.2017.12.003

[34] Wibowo, F. C., Setiawan, A., Darman, D. R., Suhandi, A., Samsudin, A., Faizin, M. N., Supriyatman, Anriani, N., Nurhaji, S., Fawaid, M. (2021). Effectiveness of Virtual Physics Laboratory (VPL) with Dry Cell Microscopic Simulation (DCMS) to Promote of Inquiry Activity about the Battery. *J. Phys.: Conf. Ser.* 1772 012006, 1-6.

[35] Yilmaz, R. M., & Goktas, Y. (2017). Using augmented reality technology in storytelling activities: examining elementary students' narrative skill and creativity. *Virtual Reality*, 21(2), 75-89.

[36] Yousef, A.M.F. (2021). Augmented reality assisted learning achievement, motivation, and creativity for children of low-grade in primary school. *Journal of Computer Assisted. Learning*. DOI: 10.1111/jcal.12536

[37] Zhang, Jia; Huang, Yu-Ting; Liu, Tzu-Chien; Sung, Yao-Ting; Chang, Kuo-En (2020). Augmented reality worksheets in field trip learning. *Interactive Learning Environments*, (), 1–18. doi:10.1080/10494820.2020.1758728

[38] Zhang, Z., Xu, G., Gao, J., Wang, L., Zhu, Y., Li, Z., & Zhou, W. (2020). Effects of E-Learning Environment Use on Visual Function of Elementary and Middle School Students: A Two-Year Assessment—Experience from China. *International Journal of Environmental Research and Public Health*, 17(5), 1560. doi:10.3390/ijerph17051560