Integrating Traditional Musical Instrument into Mobile Augmented Reality: The Effect on Creative Thinking and Attitudes in Science Learning

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Manuscript received January 29, 2024; revised April 24, 2024; accepted June 7, 2024; published October 15, 2024

***Abstract*—This study aims to investigate the integration of traditional musical instruments '*Angklung*' and Mobile Augmented Reality (AR) in science learning activities. The activity is intended to stimulate students' creative thinking and cultivate a positive attitude towards science learning. The instrument for measuring creative thinking consists of four essays based on indicators of creative thinking: fluency, flexibility, originality, and elaboration. The instrument of students' attitudes consists of relevance and satisfaction aspects, with nine questions for each aspect. The study used a one-group pre-and post-test design on 32 8th-grade students at one of the junior high schools in West Java Province, Indonesia. The study procedure is a pre-test, learning activity using Mobile AR, post-test, and survey distribution. The study found differences in the pre-and post-test scores of students, with N-gain scores for all indicators of creative thinking ranging from 0.41 to 0.48, including in the "Medium" category. The survey results indicate that students' attitudes towards relevant and satisfaction aspects have average scores of 3.53 and 3.58, respectively, classified as "Very Good". Consequently, this study concludes that integrating traditional musical instruments into Mobile AR affected creative thinking and fostered positive attitudes in science learning. The results of this study provide valuable insights for developing innovative educational strategies.**

***Keywords*—*Angklung*, attitude, creative thinking, mobile augmented reality, science learning**

I. Introduction

The tremendous development of technology has influenced all aspects, including education. Integrating technology into education is increasingly important for creating engaging and effective learning experiences [1]. Technology can help students understand situations and problems in the real world by visualizing or simulating science concepts [2]. One of the most popular technologies today is the mobile phone, which almost every student owns and frequently uses [3]. In education, using mobile phones for learning is familiar with mobile learning [4]. Also, Augmented Reality (AR) is a technology that can simultaneously show real and virtual environment [5, 6]. Combining mobile learning with AR technology is a new novelty in education called Mobile AR [7]. Mobile AR allows students to view and interact with digital elements added to the real world through mobile phones. Implementing Mobile AR can present visual objects in Three Dimensions (3D), improving students' interest as a new learning experience and enhancing their understanding of science concepts [8, 9].

Mobile AR has the potential to be integrated with cultural elements. Previous research has found that integrating local culture into science curriculums can build a learning environment that relates to students' daily lives and create meaningful learning [10, 11]. In Indonesia, various local cultures have potencies to be integrated into science learning. Traditional musical instruments have been used to engage Indonesian students in a discussion about the sound wave concept [12−14]. In the west part of Java Island in Indonesia, the Sundanese culture can be seen through traditional musical instruments called "*Angklung*" with which most students are familiar. Using AR, traditional musical instruments can be presented interactively in the learning environment, allowing students to learn scientific concepts through fun and meaningful experiences.

Physics as a part of science education is considered to be difficult by many students in secondary school. Students view physics as conceptually complicated, abstract, and enjoyable only for exceptionally talented students [15]. Therefore, it becomes a challenge for teachers to find innovative approaches to overcome these problems and increase student engagement. Integrating traditional musical instruments into Mobile AR offers a unique approach to making science learning more engaging and relevant. Through AR, students can interact with traditional musical instruments virtually, observe and learn the scientific concepts contained in the traditional musical instruments [16, 17]. Students' experiences relating to concrete in real-life situations may create meaningful learning [18].

Students' learning experiences can be enriched by integrating traditional musical instruments into science learning, enhancing cognitive and affective aspects [19, 20]. Traditional music has the power to influence emotions and enhance creative thinking skills [21]. AR technology holds great potential to improve students' creative thinking skills in science learning [22]. AR can help students understand complex concepts, stimulate their imagination, and encourage them to think creatively through interactive and engaging learning experiences [23]. Therefore, integrating traditional musical instruments into Mobile AR can improve creative thinking in science learning. Utilizing traditional musical instruments within AR environments can stimulate

doi: 10.18178/ijiet.2024.14.10.2168

students' imagination, foster exploration, and encourage them to integrate scientific concepts into everyday experiences [24].

In the industrial revolution era, with significant growth of advanced technology, students must be prepared with creative thinking skills. Creative thinking involves essential skills such as fluency, flexibility, originality, and elaboration [25−27]. Nowadays, science curricula must cultivate creative learning, which is essential for preparing students to meet the demands of the 21st century. Creative thinking skills can be nurtured in science education through experimentation, exploration, and applying scientific concepts in real-world contexts [28]. AR technology is ideal for facilitating such activities, allowing students to experiment and explore within a secure and controlled environment [29].

Integrating local culture into science learning can increase students' motivation [30]. Through AR technology, traditional musical instruments can be digitally replicated within the classroom environment, providing students with visual, auditory, and interactive experiences that enhance engagement and learning. The immersive learning experience can enhance student engagement and encourage them to participate more actively in learning [31]. Motivation is a crucial factor that impacts students' academic achievement. Operationally, learning motivation is assessed through Attention, Relevance, Confidence, and Satisfaction (ARCS) [32, 33]. Previous studies have introduced instruments to gauge students' attitudes toward AR. Augmented Reality Applications Attitude Scale (ARAAS) was successfully developed by Díaz-Noguera, and the instrument was declared valid and reliable [34]. ARAAS focuses particularly on relevance and satisfaction, aligning closely with the ARCS. These aspects are essential for understanding students' attitudes toward implementing Mobile AR in science learning.

This study designed and implemented a science learning activity by integrating the traditional musical instrument '*Angklung*' into Mobile AR. This design aims to demonstrate how combining local culture with modern technology can create a more inclusive, engaging, and effective learning environment. The study examined the effect of integrating *Angklung* into Mobile AR on students' creative thinking and attitudes in science learning. The research questions in this study are: (1) What are the differences in pre- and post-test mean scores of creative thinking skills? (2) What are students' attitudes toward relevance and satisfaction? The findings will provide new insights for developing innovative learning strategies and enrich the literature on the utilization of AR in science education.

II. Materials and Methods

A. Research Design

This study employed a quasi-experimental design with a one-group pre-and post-test design to investigate the effect of integrating traditional musical instruments *Angklung* into Mobile AR on creative thinking and attitudes in science learning. Pre- and post-tests were administered before and after students were exposed to the science learning activity. The procedure of this study is shown in Fig. 1.

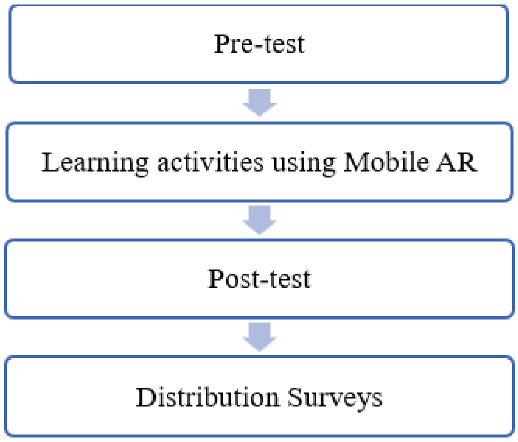


Fig. 1. Procedure of the study.

Before the learning activity, a pre-test was administered to assess students' creative thinking skills. Then, students would participate in learning activities by integrating traditional musical instruments into Mobile AR. Immediately following the learning activity, a post-test was administered to measure the changes in creative thinking skills. After completing the post-test, surveys were distributed to students. These surveys were designed to gather opinions on students' attitudes toward the learning experience.

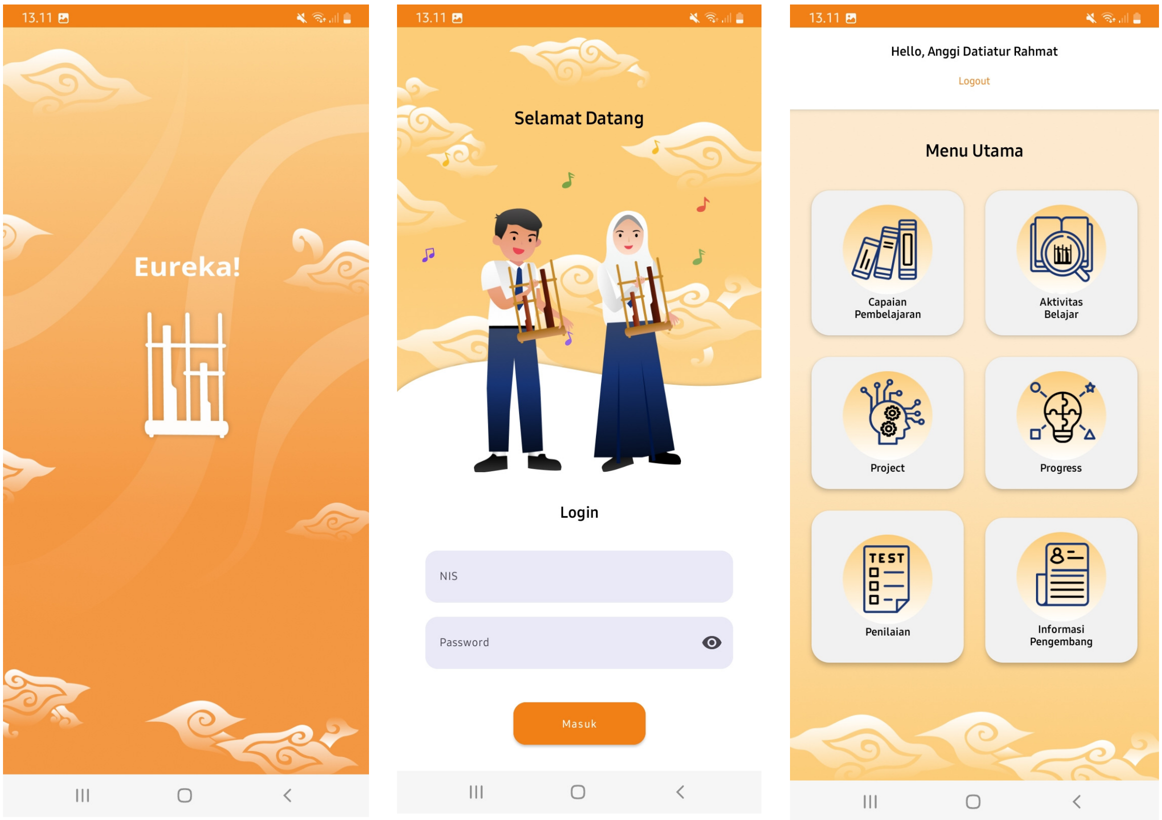
B. Participants

This study's participants were 32 students in the 8th-grade class of the junior high school who were learning science in the classroom. The participants are 14 males and 18 females, with an average age of 14-15 years. All participants owned a smartphone and had previous experience using smartphones for learning purposes. The study's location is one of the state junior high schools in West Bandung, Indonesia, in semester 2 of 2023. Based on information from science teachers, learning science using mobile AR was first conducted at this school.

C. Design of Mobile AR

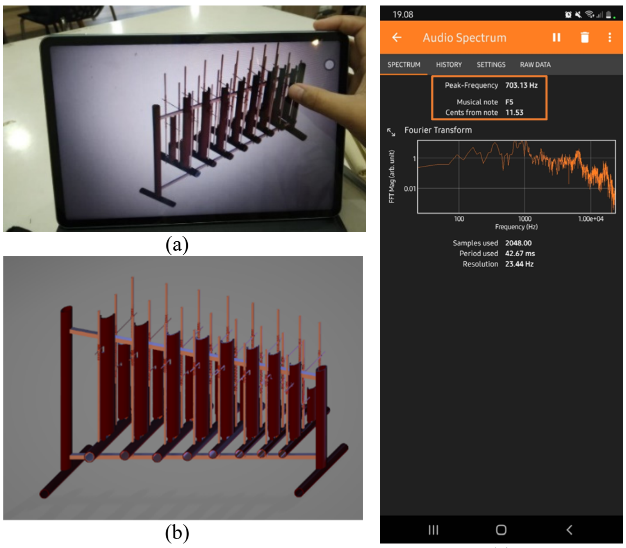
The wave sound concept was chosen because it relates to the *Angklung*, which can visualize wave sounds in a new learning environment. The Mobile AR developed is named '*EUREKA!*' (an acronym for Elaborating Augmented Reality and *Angklung*). This media has been validated by two lecturers and two practitioners, who are experts in physics content and learning media. The design of the Mobile AR-integrated traditional musical instrument *Angkung* is shown in Fig. 2.

The traditional musical instrument *Angklung* is featured virtually in the developed Mobile AR. Integrating *Angklung* into Mobile AR offers an interactive learning experience, allowing students to learn and play the 3D *Angklung* simulation (See Fig. 3). When the body of the *Angklung* is clicked, one of them will produce sounds corresponding to the instrument's tones. These sounds are recorded from *Angklung* performances by a professional team from Saung Angklung Udjo, renowned for their expertise in *Angklung* performances in Indonesia. The frequencies of these sounds are then identified using the *Phyphox* app (an acronym for physical phone experiments), as shown in Fig. 3(c).



(a) (b) (c)

Fig. 2. Design of Mobile AR integrated *Angklung* (a) Splash screen; (b) Login; (c) Menu.



(a)

(b)

(c)

Fig. 3. *Angklung* 3D simulation on Mobile AR (a) Snapshot on the tab; (b) *Angklung* 3D; (c) Display frequencies on *Phyphox* app.

D. Data Collection Instrument

The instruments used in this study are pre-test and post-test to investigate how integrating traditional musical instruments into Mobile AR affects students' creative thinking skills. The instrument consists of four essays. The example of the instruments used in this study is shown in Fig. 4. Each question has a maximum score of 4. The developed scoring guidelines are based on analytical scoring. This method is suitable for test questions with clear and specific answers [35]. The total score is then multiplied by 6.25 to obtain the final score, with a maximum score of 100. Question indicators in this study are shown in Table 1.

Table 1. Question indicator of creative thinking

Indicator	Question Indicator
Fluency	Students can provide ideas that are appropriate to the problems related to the traditional musical instrument *Angklung*.
Flexibility	Students can solve problems related to the sound frequency of *Angklung* music using various methods to represent it.
Originality	Students can develop an experimental design to identify the effect of the length of the sound tube in the *Angklung* on sound frequency.
Elaboration	Students can modify the *Angklung* with their designs to make it more efficient to use in performances.

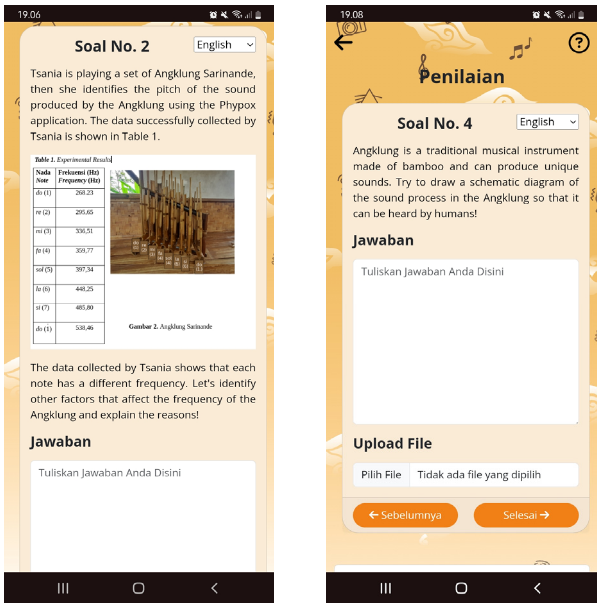


Fig. 4. The instrument of this study

Surveys were distributed after the post-test to capture qualitative data on student attitudes. The instruments utilized in this study were adapted from the Augmented Reality Applications Attitude Scale (ARAAS) developed by Díaz-Noguer [34], focusing specifically on the aspects of relevance and satisfaction. The survey statements were modified for junior high school students and contextualized to the Indonesian setting, emphasizing the traditional musical instrument *Angklung*. The survey consists of 9 questions in each aspect with positive and negative statements.

E. Data Analysis

To compare pre-and post-test results, the normalized gain $\langle g \rangle$ was used to measure the improvement in students' creative thinking skills after participating in science learning using Mobile AR integrated *Angklung*. The formula for calculating the normalized gain is presented in Eq. (1). The normalized gain score is classified using criteria provided by Hake (1998), as shown in Table 2.

$$\langle g \rangle = \frac{\%post - \%pre}{100 - \%pre} \tag{1}$$

where %post is the percentage post-test score, and %pre is the percentage pre-test score.

Table 2. Criteria of normalized gain score [36]

Normalized Gain $\langle g \rangle$	Criteria
$\langle g \rangle \geq 0.7$	High
$0.3 \leq \langle g \rangle < 0.7$	Medium
$\langle g \rangle < 0.3$	Low

The survey consists of positive and negative statements, and the results must be converted [37]. The student's answers to positive statements are converted into scores such as "strongly agree" = 4, "agree" = 3, "disagree" = 2, and "strongly disagree" = 1. Meanwhile, scoring for negative statements is the opposite of positive statements, such as "strongly disagree" = 4, "disagree" = 3, "agree" = 2, and "strongly agree" = 1. The conversion results are calculated, and the mean score is interpreted using criteria, as shown in Table 3.

Table 3. Criteria for the average score of students' attitudes [38]

No.	Score interval	Criteria
1	$\bar{x} > 3.4$	Very Good
2	$2.8 < \bar{x} \leq 3.4$	Good
3	$2.2 < \bar{x} \leq 2.8$	Acceptable
4	$1.6 < \bar{x} \leq 2.2$	Poor
5	$\bar{x} \leq 1.6$	Very Poor

III. Result and Discussion

A. The Effect on Creative Thinking Skills

The study found that students' creative thinking skills changed before and after the learning activity using Mobile AR. Indicators of creative thinking skills were selected as fluency, flexibility, originality, and elaboration. This indicator was chosen because it follows the context of real-life found by the students, especially focusing on the traditional musical instrument *Angklung*. The difference between the pre-and post-test for each indicator in creative thinking skills can be seen in Fig. 5.

The mean scores of students' creative thinking skills show an improvement between the pre-test and post-test. Each indicator of creative thinking skills demonstrates improvement from the pre-test to the post-test, as illustrated in Fig. 5. To quantify this difference, normalized gain scores were calculated, and improvement criteria for each indicator were established, as shown in Table 4.

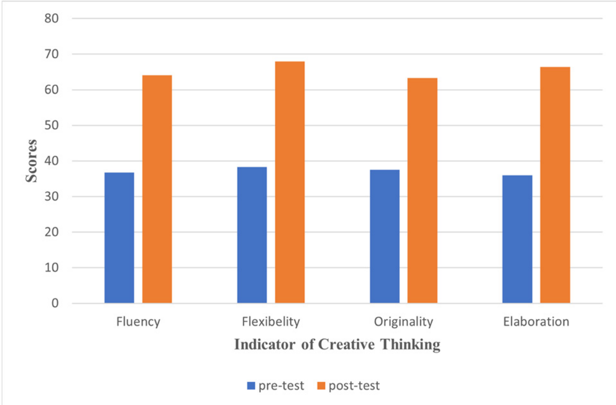


Fig. 5. Differences between pre-and post-test mean scores.

Table 4. The normalized gain score of each indicator of creative thinking

Indicator	Pre-test average	Post-test average	N-gain score	Criteria
Fluency	36.71	64.06	0.43	Medium
Flexibility	38.28	67.96	0.48	Medium
Originality	37.50	63.28	0.41	Medium
Elaboration	35.93	66.40	0.48	Medium

Normalized gain scores for each indicator of creative thinking show improvement with medium criteria. Integrating traditional musical instruments into Mobile AR introduces a new learning experience for students, stimulating their creative thinking skills. Using Mobile AR integrated with traditional musical instruments can be presented interactively in science learning, allowing students to learn scientific concepts through fun and meaningful experiences. Integrating traditional musical instruments into Mobile AR can facilitate students' virtual interaction with objects and their observation and learning of the scientific principles contained in musical instruments. Traditional music can influence emotions and enhance creative thinking skills [21]. Utilizing traditional musical instruments in the context of AR has the potential to stimulate students' imagination, foster exploration, and encourage the integration of scientific concepts into everyday life [24]. Furthermore, AR enables students to visually perceive, audibly experience, and interact with these instruments within an engaging and interactive learning environment.

Implementing Mobile AR facilitates the presentation of visual objects in 3D format and improves students' interest as a new learning experience [39, 40]. The 3D simulation and sounds produced by the *Angklung* can enhance their creativity and reconstruct scientific concepts [41]. *Angklung* has various tones and forms and stimulates flexibility in understanding phenomena, encouraging creative thinking skills in students [42]. *Angklung*, an original traditional musical instrument from West Java, supports contextual learning and enhances originality skills as one aspect of creative thinking [43]. Originality in innovation and creation is imperative for science education to meet the challenges of the 21st century. Experimental activities integrated with Mobile AR technology can enhance students' elaborative skills, facilitating the development of ideas for existing products [44].

Integrating traditional musical instruments into Mobile AR to teach wave sound concepts has been successfully implemented to enhance creative thinking skills. AR allows students to interact dynamically and in real time with sound wave simulations [45]. AR helps students visualize complex and abstract concepts on sound waves. By directly observing how waves interact and transform, students can innovate new methodologies for comprehending the concept of sound waves [46, 47]. Flexibility in understanding a concept is one aspect of creative thinking. Additionally, AR creates an immersive learning environment. The experiences that students experience through learning using Mobile AR can trigger students' imagination and creativity because they feel directly involved in the learning process [48]. Integrating traditional musical instruments into Mobile AR involves various scientific disciplines including physics, music, and technology. This multidisciplinary approach fosters creative thinking skills by showing how concepts from different fields can be combined [49].

Integrating technology into science learning promotes student-centered learning and cultivates 21st-century skills, including creative thinking skills. Previous research found that learning without technology, which is teacher-centered, may be less stimulating for students regarding their creativity [50]. Students are more engaged in science learning when recent technology is involved. Integrating technology has a positive impact on enhancing learning achievement [51]. Presenting daily life phenomena in science learning is crucial, it can be a stimulus for students to understand science concepts. Integrating local culture into science learning empowers students to articulate their ideas based on cultural insights, thereby enhancing their creative thinking skills. AR, as a technology for interactive presentation, has the potential to enhance these creative thinking skills further [52].

B. The Effect on Attitudes of Student

The student attitudes identified in this study focus on relevance and satisfaction aspects. The results of students' attitudes in learning science for relevant aspects are shown in Table 5. Integrating traditional musical instruments into Mobile AR affects student relevance in science learning. The results of this study found that the average score of students' attitudes regarding relevance was 3.53, with the criteria "Very Good". The result of students' attitudes in relevant aspects indicates that students show very positive attitudes toward using the Mobile AR-integrated traditional musical instrument *Angklung* in science learning.

The lowest score was found in the statement number 6, "waste time" ($\bar{x}$ = 3.19), with 2 students answering "agree," 22 students answering "disagree," and 8 students answering "strongly disagree." These results indicate that learning activities using Mobile AR integrated *Angklung* do not waste time because more than 50% of the total survey participants disagreed with this statement. Previous research found AR applications exciting and accessible [53]. In particular, wasting time in AR technology applications can occur the first time because of technical constraints such as unreadable markers, camera scans affected by lighting, and inadequate smartphone specifications [54].

Table 5. Student's attitude toward the relevance aspect

No	Statement	Strongly Agree	Agree	Disagree	Strongly Disagree	Average Score	Criteria
1	I get bored while I am using Mobile AR-integrated *Angklung* in science learning	0	0	9	23	3.72	Very Good
2	It is complicated to use Mobile AR and *Angklung* in science learning	0	0	8	24	3.75	Very Good
3	Mobile AR shows 3D of *Angklung* as objects, providing a feeling of reality	18	14	0	0	3.56	Very Good
4	Studying science topics is more difficult when integrating *Angklung* into Mobile AR	0	1	17	14	3.41	Very Good
5	I want to use AR technology in other science topics and use other local cultures more	17	15	0	0	3.53	Very Good
6	The use of Mobile AR-integrated *Angklung* in science learning is a waste of time	0	2	22	8	3.19	Good
7	Integrating *Angklung* into Mobile AR makes my science learning difficult because it confuses my mind	0	2	13	17	3.47	Very Good
8	There is no need to use Mobile AR and *Angklung* in science learning	0	3	15	14	3.34	Good
9	Integrating *Angklung* into Mobile AR improved my knowledge of content in science learning.	27	5	0	0	3.84	Very Good
	Average					**3.53**	**Very Good**

The highest score in the relevance aspect was found in the statement number 9, "improve knowledge" ($\bar{x}$ = 3.84), where 27 students "strongly agree" and 5 students answered "agree." These results interpreted that using Mobile AR-integrated *Angklung* in science learning can improve students' knowledge. These results align with previous studies that found that using AR can increase learning achievement [24, 46, 55], critical thinking [56, 57], and problem-solving [58−60]. The results of students' attitudes toward learning science with satisfaction are shown in Table 6.

Table 6. Student's attitude of satisfaction aspect

No	Statement	Strongly Agree	Agree	Disagree	Strongly Disagree	Average Score	Criteria
1	I gained better focus on the science topic when using Mobile AR-integrated *Angklung*	21	11	0	0	3.66	Very Good
2	Demonstration of 3D simulation of *Angklung* in Mobile AR increased my curiosity in science learning	19	13	0	0	3.59	Very Good
3	I attended science learning with enthusiasm when integrating *Angklung* into Mobile AR	20	12	0	0	3.63	Very Good
4	I enjoy learning science when integrating *Angklung* into Mobile AR is used	15	17	0	0	3.47	Very Good
5	Implementing Mobile AR-integrated *Angklung* in science learning does not catch my attention	0	3	14	15	3.37	Good
6	I feel happy when integrating *Angklung* into Mobile AR in science learning	23	9	0	0	3.72	Very Good
7	Using Mobile AR-integrated *Angklung* motivates me to learn science	28	4	0	0	3.87	Very Good
8	I feel more involved in learning using Mobile AR-integrated *Angklung* than textbooks in a more theoretical manner	14	17	1	0	3.41	Very Good
9	Science learning using Mobile AR-integrated *Angklung* shows that the content is interesting.	17	15	0	0	3.53	Very Good
	Average					**3.58**	**Very Good**

Implementing Mobile AR-integrated *Angklung* in science learning affects student satisfaction. The results show that the average score of students' attitudes toward satisfaction is 3.58, according to the criteria "Very Good." It can be interpreted that students show very positive attitudes toward science learning. The lowest score in the satisfaction aspect was found in statement number 5, "not catch attention" ($\bar{x}$ = 3.37). These results indicate that using Mobile AR integrated *Angklung* in science learning catches students' attention. Implementing AR technology affects students' motivation, especially attention [24]. The highest score in the satisfaction aspect was found in statement number 7, "motivates to learn" ($\bar{x}$ = 3.87). The findings indicate that the integration of *Angklung* into Mobile AR can effectively stimulate student engagement in learning. The implementation of Mobile AR has been observed to influence students' motivation in learning [61], particularly in science education, where AR usage enhances students' overall motivation to engage with the subject [62].

The relevance aspect demonstrated that students do not get bored using Mobile AR-integrated *Angklung* in science learning. The technology is perceived as straightforward, provides a realistic experience, and is user-friendly, prompting students' interest in applying it to other scientific topics. AR technology has great potential for use in science learning [63]. Additionally, satisfaction revealed that students exhibit improved focus, heightened curiosity and enthusiasm, increased enjoyment and happiness in learning, and a sense of active participation and engagement. As a result, students demonstrate positive attitudes toward learning when utilizing Mobile AR-integrated *Angklung*.

Integrating the traditional musical instrument *Angklung* into Mobile AR not only improves students' creative thinking skills but also enriches their attitudes towards science learning. Mobile AR allows students to interact directly and immersive with learning materials, increasing engagement and interest in science learning. The combination of technology and traditional musical instruments encourages students to think creatively. The limitation of this study is the use of the traditional musical instrument *Angklung* originally from West Java that students only know from the area, so if they are to be widely implemented, it is necessary to describe how to play the traditional musical instrument first. Future research can integrate other local cultures adapted to the area or science concept to be taught.

IV. Conclusion

This study designed and implemented a science learning activity by integrating the traditional musical instrument '*Angklung*' into Mobile AR. The study found differences in the pre-and post-test scores of students, with N-gain scores for all indicators of creative thinking ranging from 0.41 to 0.48, including in the "Medium" category. The survey results indicate that students' attitudes towards relevant and satisfaction aspects have average scores of 3.53 and 3.58, respectively, both classified as "Very Good" categories. Therefore, integrating traditional musical instruments *Angklung* into Mobile AR affected creative thinking and attitude in science learning. The result of this study can be used as a reference for integrating technology and local culture into another science concept.

Conflict of Interest

The authors declare no conflict of interest.

Author Contributions

ADR conceived the work, designed the research strategy, and made the instruments. IW and ADR conducted the pilot study. HK, DS, and ADR analyzed the data. ADR and ANMD reviewed and edited the manuscript. All authors have read and agreed to the published version of the manuscript.

Funding

This work was supported by the Indonesian Ministry of Education, Culture, Research, and Technology for funding this study through a *Pendidikan Magister menuju Doktor untuk Sarjana Unggul* (PMDSU) scheme with grant number T/105.1.107 /UN34.9/PT.01.03/2024.

Acknowledgment

The author sincerely thanks Universitas Negeri

Yogyakarta Universitas Negeri Yogyakarta, SMP Negeri 1 Sindangkerta, and the Education Office of West Bandung Regency for their invaluable support and contributions to this study.

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