Integrating Neuroscience-Based Augmented Reality Media for Character Education

Yessy Yanita Sari[1,*], Arum Fatayan[1], Gea Pandhita[2], Sartika Ayu[1], Ika Yatri[1], and Habibah Nurfauziah[3]

[1]Postgraudate Department of Elementary Education, Muhammadiyah Prof. Dr. Hamka University, Jakarta, Indonesia
[2]Faculty of Medicine, Muhammadiyah Prof. Dr. Hamka University, Jakarta, Indonesia
[3]Faculty of Computer Science, Muhammadiyah University of Science and Technology, Jakarta, Indonesia
Email: yessy.syah@uhamka.ac.id (Y.Y.S.); arum_fatayan@uhamka.ac.id (A.F.); geapandhita@uhamka.ac.id (G.P.); sartikaayu16022000@gmail.com (S.A.); ikayatri@uhamka.ac.id (I.Y.); habibah.nurfauziah@saintekmu.ac.id (H.N.)
*Corresponding author

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***Abstract*—This study aims to analyze the effectiveness and attitudes of students in integrating neuroscience-based augmented reality media to improve the character education value of elementary school students in Indonesia—the research and development method with the 4D model (Define, Design, Develop, and Disseminate). The data analysis technique uses quantitative and qualitative results obtained from validation using a trial of neuroscience-based augmented reality media. This study involved 162 elementary school students in phases B to C. In this study, the effectiveness of neuroscience-based augmented reality media was proven by the difference in pre-test and post-test scores of students according to the character value indicator of 0.40 to 0.55 with a moderate category. The attitude of relevance and satisfaction results showed an average score of 87.03, an outstanding category. Then, there is a significant influence on students' attitudes towards using neuroscience-based augmented reality media, namely p = 0.000 < 0.05. Integrating neuroscience-based augmented reality media can significantly affect the value of elementary school students' character education.**

***Keywords*—neuroscience-based, augmented reality, character education**

I. Introduction

Technology is an inseparable need in 21st-century life, and technological developments are increasingly widespread in all fields, including education [1]. Technological innovations in education are increasingly varied to be able to transfer knowledge, skills and character education to students [2]. Technology can help students understand a problem concretely [3, 4]. This is because 3-dimensional technology that can combine the real world with virtual is called Augmented Reality (AR) [5, 6]. This augmented reality technology can be used as an innovative learning medium. The use of technology can stimulate students' imagination.

The integration of augmented reality media with neuroscience is a powerful tool to improve character education for students in elementary schools. For example, it can be used to create interactive scenarios that teach empathy and decision-making. Research has shown that this integration not only enhances the learning experience but also significantly increases students' positive emotions, thereby creating a more conducive learning environment [6]. Neuroscience is a science that studies the human nervous system, such as student character [7, 8]. Augmented reality media will be developed per the theory of human development. This is because of the importance of student character education in brain function in controlling body movements, assessing and planning something, solving problems, and regulating emotions and self-control [9, 10]. Using neuroscience-based augmented reality, character education values can be presented interactively and meaningfully [11].

Character education is a problem that needs to be optimally resolved, especially at the elementary school level [8, 12]. Based on data obtained from the Indonesian Child Protection Commission (KPAI) in 2023, it showed around 3,800 cases of bullying [13]. This is because there is still a lack of integration of character education values from an early age. In addition, it is essential to improve the character education of elementary school students by the goals of the Indonesian National Education. Therefore, it is a challenge for teachers to be able to instill character education through innovative media and approaches [14, 15]. Integrating neuroscience-based augmented reality media containing character education values offers an exciting and relevant learning experience [16, 17]. Through augmented reality, students can interact with story illustrations that virtually contain the cooperation's character values. Students' learning experiences become more concrete with real-life situations. In addition, it can affect students' thinking skills in taking action [18, 19].

Based on the results of interviews and observations in elementary schools regarding the learning media used, it was revealed that the dynamics in Indonesian schools are unevenly distributed in facilities such as projectors in each class. Students tend only to be spectators and observers of learning materials. Thus, technology as a learning medium still needs to be improved. Cannot feel, do, and experience directly using learning media. This allows researchers to develop 3D teaching media, which is much needed to support learning.

Neuroscience-based augmented reality media has great potential to improve the value of character education. Augmented reality can make it easier for students to understand complex concepts, stimulate imagination, create meaningful learning experiences, and increase students' interest in learning [20, 21]. Technology must be utilized positively so that students can be wise in choosing and using this increasingly rapid technology. Character education must involve elaboration [22].

Previous research has used augmented reality media in neuroanatomy learning to ease the cognitive load and motivate students, which was successfully developed by

Kerem A. Bolek *et al.* [23]. The results of this study stated that augmented reality media helps and motivates students to learn. The advantages of this study integrating neuroscience-based augmented reality media increase the value of character education for elementary school students in Indonesia, namely the use of media that attracts students' attention and the design of learning media that is adjusted to the theory of child development (neuroscience). Thus, the development of this media has a solid theoretical basis in creating student story designs, such as the selection of colours and characters. The goal is for students to understand and consider the message conveyed in the story on augmented reality media more efficiently regarding character education students must have.

This study develops and integrates neuroscience-based augmented reality media containing character education values for elementary school students in Indonesia. This design aims to show how to combine character education values with augmented reality technology that emphasizes the development of student development theory and neuroscience. This study tests the effectiveness of neuroscience-based augmented reality media for character education. The research questions in this study are: (1). How effective is neuroscience-based augmented reality media for character education? (2). What are students' attitudes towards the relevance and satisfaction of neuroscience-based augmented reality media? This study is expected to contribute significantly to the field of character education in elementary schools, especially in developing more effective, engaging, and holistic learning media.

II. Literature Review

Augmented Reality (AR) is a technology created in 1960 by Ivan Sutherland, a computer scientist from the United States. The initial aim of augmented reality was to explore human interaction with computer graphics in 3D form [24]. As the times change, augmented reality technology is progressing. One of its applications is in education, where it enhances virtual content such as 3D objects, text, audio, and video [25]. These elements can be combined and presented realistically, thanks to the concept of absolute terms. And the best part? All this can be achieved with the help of a smartphone [26].

Augmented reality can be one of the latest innovations in learning activities. Augmented reality can only be used for free, requiring an adequate internet network [27]. Attractive visuals can increase students' motivation and interest in learning [4, 28].

Integration of neuroscience-based augmented reality to improve students' character education through attractively designed story illustrations. In addition, the selection of illustration colors is based on the development of elementary school students [29, 30]. This augmented reality media is designed with several series of interrelated story illustrations.

Several theories of child development, such as Piaget's stages of cognitive development and Vygotsky's sociocultural theory, are used as the design concept for neuroscience-based augmented reality media illustrations. These theories guide the creation of illustrations that are not only visually appealing but also cognitively stimulating shows in Table 1.

Table 1. The concept of objects in illustrations of child development theory [31–38]

Illustration Objects	Development Theory
Illustration 1 A mother is preparing her child to participate in school community service activities.	▪ Eccles & Wigfield on emotional support and parental encouragement. ▪ Bronfenbrenner on social ecology theory, namely the environmental system that supports children to have good attitudes.
Illustration 2 Several children work in groups in cooperation activities in the schoolyard.	▪ Regarding cognitive development, Piaget believes that elementary school children are still at the concrete operational stage, such as thinking logically and understanding other people. Hence, there needs to be a foundation of good cooperation with the surrounding environment.
Illustration 3 The teacher is giving directions to students on how to decorate the classroom.	▪ Vygotsky's ZPD theory is about elementary school-age children who still need help from adults.
Illustration 4 The teacher accompanies students in tidying up the school library.	▪ Kohlberg's involvement, role model theory, and ethical and moral theory.
Illustration 5 Each child is given the responsibility of tidying up the classroom.	▪ Kohlberg's moral development theory states that elementary school-age children can understand and obey applicable social rules.
Illustration 6 A series of cooperation activities to welcome new students is complete, and the teachers show appreciation to the students.	▪ Bandura's social learning theory of cooperation through observation, experience, giving, and affirmation is carried out directly on elementary school children.

III. Materials and Methods

A. Research Design

This study uses the Research and Development (R&D) method with the 4D model (Define, Design, Develop, and Disseminate) [19]. This method can create effective products using neuroscience-based augmented reality media to form character education for elementary school students.

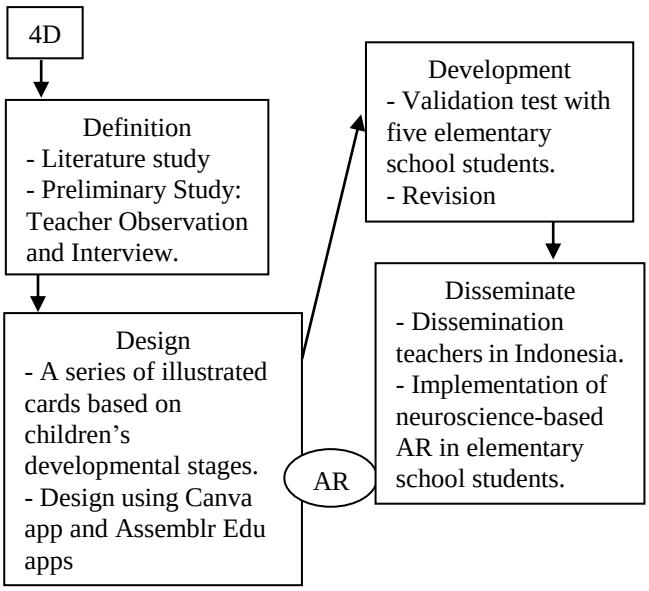

Fig. 1. Research flow of definition, design, development, and disseminate of learning media AR for elementary school students.

Fig. 1 shows before implementing neuroscience-based AR media, a pre-test was conducted to determine the initial condition of students' understanding of character education.

B. Participants

The participants of this study were 162 elementary school students in phases B to C. The participants comprised 94 girls and 68 boys with an average age of 9−12 years. All participants had smartphones that had downloaded the Assemblr Edu application as an application of augmented reality technology.

C. Neuroscience-Based AR design

At the design stage, the researcher first designed the AR media, which consisted of a physical form of illustrated serial cards. There are six cards containing serial stories with the theme of cooperation. The theme of cooperation was chosen to answer the character problems encountered in previous research: discipline, responsibility and cooperation. The images on each card were designed based on the theory of moral development of elementary school children.

The images were designed using Canva media. Canva Media is an interactive application with attractive designs and features for presentations, posters, games, pamphlets, etc [39, 40]. Canva media can be used online, and serial illustration images 1 to 6 can be revised.

Fig. 2. Illustration 1 a mother is preparing her child to participate in school community service activities.

Fig. 2 shows Cici and her mother preparing cleaning equipment that Cici will bring to school for cooperation activities and welcoming new students. Cici brings a broom from her mother.

Fig. 3. Illustration 2 several children work in groups in cooperation activities in the schoolyard.

Fig. 3 shows Cici and her friends mutually cooperate in the schoolyard after arriving at school. Cici and her friends shared tasks to make it easier to clean the schoolyard.

Fig. 4. Illustration 3 the teacher is giving directions to students on how to decorate the classroom.

Fig. 4 shows students and teachers decorate the school walls to make them look beautiful. Mr. Joko helps and supervises the students. At the same time, Cici and Agus are in charge of painting the walls. Ina and Farhan are in charge of making hand-painted paintings.

Fig. 5. Illustration 4 the teacher accompanies students in tidying up the school library.

Fig. 5 shows in the library room, Cici and Ina are helping Mrs. Dewi tidy up the books. Ratna is busy reading a book.

Fig. 6. Illustration 5 each child is given the responsibility of tidying up the classroom.

Fig. 6 shows students cleaning the classroom by sharing each person's tasks and responsibilities.

Fig. 7. Illustration 6 a series of cooperation activities to welcome new students is complete, and the teachers show appreciation to the students.

Fig. 7 shows students who have finished gathering in the school hall to prepare the room. Mr. Alam and Mrs. Dewi arranged and directed students to tidy the tables and chairs.

D. Data Collection Instruments

The research instrument includes a pre-test and post-test to analyze the effectiveness of neuroscience-based augmented reality media in students' character education values. The instrument consists of five essays distributed through Google Forms. Each question has a maximum score of 5. The total score will be multiplied by 4 to obtain a maximum score of 100.

Table 2. Character indicators [41]

Indicators	Response
Responsibility	Students can be responsible for the tasks given to them.
Honesty	Students will speak according to the truth (case study).
Discipline	Students can manage time (case study).
Flexibility	Students can adjust their characters based on certain situations and conditions.
Elaboration	Students can understand the behavior that will be carried out in real life.

Table 2 shows this instrument is used before and after using augmented reality media to determine whether students' understanding of Character Education has changed.

Table 3. Character instruments

Indicators	Statement	Score				
		1	2	3	4	5
Responsibility	I always complete my schoolwork by myself and on time.	0	0	2	160	0
Honesty	I always tell and speak according to the truth of what I see, hear, and do.	0	0	10	80	72
Discipline	I always obey the rules I make for myself in my daily activities.	0	0	11	84	67
Flexibility	I constantly adapt to conditions in the classroom and school environment.	0	0	24	89	49
Elaboration	I always think first before doing something.	0	0	41	68	53

1 = Very poor; 2 = Poor; 3 = Neutral; 4 = Good; 5 = Very good.

The data in Table 3 before implementing the character instrument, the researcher conducted validity and reliability tests.

Table 4. Validity test

Aspects	Q1	Q2	Q3	Q4	Q5
Rcount	0.189	0.628	0.748	0.782	0.879
Rtable	0.153	0.153	0.153	0.153	0.153
Description	Valid	Valid	Valid	Valid	Valid

Q = Question.

Based in Table 4 the validation test, aspects of questions 1 to 5 are valid. This is because Rcount > Rtable. Question 1 obtained 0.189 > 0.153; question 2 obtained 0.628 > 0.153; question 3 obtained 0.748 > 0.153; question 4 obtained 0.782 > 0.153; and question 5 obtained 0.879 > 0.153.

Based in Table 5 the reliability test of the question can be reliable if cronbach's alpha value is >0.7. The results of the reliability test show that cronbach's alpha value is 0.721 > 0.7, so it can be concluded that the question is reliable.

Table 5. Uji reliability

Cronbach's Alpha Value	Description
0.721	Reliable

E. Data Analysis

This study can compare students' pre-tests and post-tests, using the N-gain score formula as quantitative and qualitative results obtained from validation using neuroscience-based augmented reality media trials.

IV. Result and Discussion

A. Effectiveness of Neuroscience-Based Augmented Reality Media for Character Education

This study shows the differences between the characters of elementary school students before and after learning to use augmented reality media. This study is supported by previous research, which found that augmented reality media effectively improves students' cognitive abilities [27]. This is proven by research that has implications for teachers and students using augmented media.

The selected character indicators include responsibility, honesty, discipline, flexibility, and elaboration. These indicators are based on students' daily lives and focus on students' character values—the difference between the pre-test and post-test results for each indicator in character education.

Table 6. N-Gain Indicators of Character Education Values

Indicator	Pre-Test	Post-Test	N-Gain Score	Criteria
Responsibility	45	72	0.49	Medium
Honesty	38	68	0.48	Medium
Discipline	36	62	0.40	Medium
Flexibility	32	70	0.55	Medium
Elaboration	36	62	0.40	Medium

Table 6 shows the normalized acquisition score for each character education indicator shows an increase in the moderate category. Integrating neuroscience-based augmented reality media creates a meaningful and enjoyable learning atmosphere. Integrating this augmented reality media can facilitate students' virtual interactions through objects and observations and learning objects that contain character values. Utilizing neuroscience-based augmented reality media in the context of character education can stimulate understanding and encourage integration into the daily lives of elementary school students.

The application of augmented reality facilitates the presentation of visual objects in 3D. 3D story illustration about the character value of cooperation in the elementary school environment. This augmented reality media has many features (objects) that can be used to design learning media containing character values according to the theory of student development in elementary schools. In addition, it can use audio and text to clarify the illustrated story containing students' character values.

Everyday life phenomena play a crucial role in character

education. By presenting these phenomena, we can train students to understand and respond to the problems in their environment [42]. This practical application of character values makes them more relevant and meaningful to students.

B. The Influence of Student Attitudes Towards the Relevance and Satisfaction of Neuroscience-Based Augmented Reality Media

Students are identified according to relevance and satisfaction—the results of students' attitudes towards the use of neuroscience-based augmented reality media. The results of this study show significance between pre-test and post-test scores, namely $p = 0.000 < 0.05$. This states that there is an influence on students' attitudes towards using neuroscience-based augmented reality media.

Table 7. T-Test

Tests	n	M (Std.D)	Paired T-Test		
			t	df	Sig. (2-tailed)
Pre-test	162	62.27 (4.13)	−45.875	161	0.000*
Post-test	162	87.03 (6.28)			

In addition, Table 7 showed the average pre-test score was 62.27, with a less good category. The application of character education integrated with neuroscience-based augmented reality media affects student satisfaction, obtaining an average score of 87.03 in the outstanding category. The application of this media has been observed to influence the character of elementary school students in learning and acting in their surroundings.

The relevance aspect states that students enjoy using neuroscience-based augmented reality media for character education. This media is easy to use, flexible, and provides a real learning experience. Then, student satisfaction is expressed by students' level of understanding, concentration, interest, and active involvement in learning activities. As a result, students have a positive attitude towards using neuroscience-based augmented reality media for character education.

This study is supported by previous studies showing that using augmented reality media can provide students with a more exciting learning reality. Thus, students feel satisfied using augmented reality media as a learning medium. This can make it easier for students to think (cognitive) and understand learning [43]. If students feel happy, interested, and curious about something, it will be easier to increase interest, learning outcomes, and student satisfaction.

Integrating improves the character values of elementary school students and students' knowledge in processing emotions and interacting appropriately with their environment. The limitation of this study is that it requires a stable internet network to use neuroscience-based augmented reality media efficiently and clearly.

Based on the development of neuroscience-based augmented reality media in designing using child development theory. This aims to facilitate the integration of augmented reality media for students in elementary schools. The selection of bright colors makes students interested in seeing the illustrations. This integration supports teachers in making learning enjoyable according to the stages of child development. Thus, future research will focus more on the character of the Pancasila Student Profile Strengthening Project in depth according to the needs of students in the development phase so that it does not become a mental burden for academic students.

V. Conclusion

This study was designed to implement character education learning by integrating neuroscience-based Assemblr Edu media. In this study, the effectiveness of neuroscience-based augmented reality media is proven by the difference in pre-test and post-test scores of students according to the character value indicator of 0.40 to 0.55 with a moderate category. At the same time, the attitudes of relevance and satisfaction show an average score of 3.00 to 3.72, which is a very good category.

Therefore, it can be concluded that the integration of neuroscience-based augmented reality media can significantly affect the character education values of elementary school students. This is because more interesting learning creates increased student learning motivation and a more concrete, tangible understanding of the character education values that must be applied according to the situation. Neuroscience works well to control students' characters in acting, providing a reassuring outcome of this study.

Conflict of Interest

The authors declare no conflict of interest.

Author Contributions

YYS designed the research strategy and created the instruments and wrote manuscript; AR analyzed the data; GP analyzed the neuroscience-based AR media; SA wrote the manuscript and designed the AR media; IY and HNF conducted the preliminary study; All authors have read and approved the published version of the manuscript.

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