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Development of STEM-Based Augmented Reality Media to Strengthen Adaptive Reasoning and Creativity Skills of Elementary School Students

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Abstract

The ability of adaptive reasoning is greatly needed to develop cognitive skills in students through mathematical observations of an object and problems caused by the aspect of creativity often being neglected because of the focus on mastery of the material, with students' answers being brief without elaboration and explanation. This research background study aims to develop STEM-based Augmented Reality (AR) learning media to assess the adaptive reasoning and creativity skills of fifth-grade students in IPAS (Science and Social Studies Integration) subjects. The research subjects included validators, teachers, and students to evaluate the media's validity, practicality, effectiveness, and user response. Validation results indicated that the media was highly feasible, with scores from content validators at 96%, media experts at 91%, and language experts at 94%. Practicality was rated at 97% by teachers and 82% by students. Effectiveness was measured using validated pretest and posttest instruments, yielding Aiken's V scores ranging from 0.91667 to 1.00, indicating a "very high" category. Student responses showed score improvements, particularly in adaptive reasoning indicators such as "evaluating the correctness of answers" and "drawing conclusions," which increased from mean scores of 6.33 and 6.27 to 6.88 and 8.3, respectively. Creativity indicators remained relatively stable between pretest and posttest, with mean scores consistently above 11 across all components. Overall, the AR-based media is considered feasible and effective for implementation in learning, although the interpretation of results should be approached with caution.

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INTRODUCTION

Curriculum serves as the fundamental foundation for learning across all levels of education, particularly in primary schools. In Indonesia, the educational system has undergone eleven curriculum revisions, with the most recent being the 2013 Curriculum. These changes are inseparable from the rapid advancement of the technological era (Muhsam, et al., 2021). The primary objective of curriculum reform is to rectify the shortcomings of previous curricula. One of the tangible actions in improving the latest curriculum is the implementation of the Merdeka Curriculum. This curriculum emphasizes a student-centered, teacher-facilitated, and school-supported approach to ensure relevant learning experiences, while encouraging exploration of new concepts closely related to everyday life (Warsidah, et al., 2022).

The implementation of the Merdeka Curriculum is still in its adaptation phase. This curriculum offers several advantages, such as the Guru Penggerak program, which contributes to enhancing the quality of teacher performance, and the Sekolah Penggerak program, which implements the Merdeka Curriculum based on students' needs. The core aim is to develop the Pancasila Student Profile, which is essential in preparing learners to face technological advancements, socio-cultural changes, environmental challenges, and the demands of the future workforce. This is achieved by emphasizing students' active and adaptive roles in the learning process Rahmadayanti & Hartoyo, 2022).

Students' active and adaptive roles are reflected in their cognitive abilities, one of which is reasoning. Reasoning refers to the process of logical thinking aimed at drawing conclusions (Kartono & Shora, 2020). According to Brodie (Niswah & Qohar, 2020) Reasoning is a cognitive process that involves reselecting acquired knowledge by connecting newly obtained information with prior knowledge. Through reasoning skills, students are able to develop their competencies in logical thinking and rational analysis. Such as analyzing, proving, evaluating, explaining, drawing conclusions, justifying, and making generalizations. Herbert (as cited in Lomri, 2023) Reasoning skills are essential for developing cognitive abilities through the mathematical observation of an object. Piaget (as cited in Marinda, 2020) It is stated that students aged 11 and above enter the formal operational stage, in which they are capable of abstract and logical thinking. Based on this theory, fifth-grade elementary school students are expected to have reached the formal operational stage or be able to think abstractly and logically. However, field observations indicate that many fifth-grade students still struggle with reasoning skills.

Several factors may contribute to the low reasoning ability of students in learning materials, including students' basic understanding of the subject matter, the approaches and methods implemented by teachers, learning conditions, students' interests and talents, the alignment of the curriculum with students' characteristics, and other related factors. Issues related to students' reasoning abilities are still found in various studies. It can be stated that the strategies employed by students in solving adaptive reasoning problems significantly influence both the outcomes and the accuracy of their solutions. The obstacles encountered include students' inability to comprehend the underlying problems, their lack of capacity to provide strong and logical arguments, and errors in delivering comprehensive explanations that require the integration of various concepts. If students' reasoning skills are not strengthened, the learning material will merely become a series of procedures and imitated examples without a true understanding of their meaning (Cahyani, 2023).

In addition to reasoning skills, creativity is another essential competency that students need to develop. Creativity serves as a fundamental asset for achieving academic success. It plays a central role in shaping students' problem-solving abilities, fostering innovation, and enabling individuals to adapt effectively to life's challenges (Baniyah, Jannah & Utama, 2023).

The ability to generate new ideas and creative solutions provides individuals with opportunities to address complex challenges

through alternative approaches. Moreover, creativity can serve as a primary driver of innovation, encouraging the development of ideas and products (Muhammad Yusuf, 2022) or new services that have the potential to bring significant improvements in various aspects of life. Creative thinking requires originality and reflection (Kadir et al., 2022). Providing students with appropriate stimuli can encourage critical thinking skills, enabling them to respond effectively and solve problems creatively during the learning process (Yusuf, 2020). In order for creative potential to grow and develop significantly, external stimuli and support are essential. Such stimuli and support can be obtained from students' immediate environments, including parents or family, school, students' daily habits, and the community or surroundings in which they grow and develop. The routines and experiences students acquire from their closest environment serve as a foundation for learning to communicate, express emotions, and foster their creativity (F.S. Putri et al., 2023).

Field observations reveal a wide range of student characteristics, particularly in terms of adaptive reasoning and creativity. Some students still face difficulties in understanding and adjusting their thinking when dealing with contextual or unfamiliar problems, indicating a lack of adaptive reasoning skills. Students tend to rely on routine problem-solving patterns and demonstrate inflexibility in connecting new information with their prior knowledge (Setiani, Permana & Nurcahyono, 2021). In addition, the lack of creativity is evident from students' low initiative in expressing original ideas or alternative solutions to the problems they encounter. This condition may be attributed to learning habits that place greater emphasis on memorization rather than exploration and open-ended problem solving (Nugraha, Nuryadi & Hadayanto, 2022). The results of observations related to the reasoning abilities of fifth-grade students indicate that many students have not yet been able to fully utilize their adaptive reasoning skills in the IPAS (Science and Social Studies Integration) subject.

Another stimulus that can foster student development and create meaningful learning experiences is the use of engaging instructional models, such as the STEM learning model. STEM strongly supports students' skills in facing the demands of the 21st century, as it integrates digital technology into the learning process (Maula & Fatmawati, 2020). According to (Zuryanty et al., 2020) he benefits of STEM learning through technology lie in its ability to shape students to socialize, engage in organizational activities, and enhance creativity, while also fostering social awareness and creative expression. The use of a STEM approach aims to equip students with an integrated understanding of the four interconnected STEM aspects—creativity, critical thinking, collaboration, and communication—within a single topic of study. Furthermore, it enables students to develop problem-solving skills and draw conclusions from prior learning experiences by applying knowledge through science, technology, engineering, and mathematics. The ultimate goal is to provide meaningful learning that systematically balances concepts, knowledge, and skills. STEM empowers students to apply essential life principles, training them to communicate, collaborate, engage in higher-order thinking, and demonstrate impactful creativity.

Data obtained during the observation indicated that the level of adaptive reasoning and creativity among fifth-grade elementary school students remained low. This was evidenced by data collected through interview questionnaires and pretest items designed to assess students' abilities prior to receiving any instructional stimulus. Some students expressed boredom with conventional learning media and demonstrated a lack of understanding of the material "My Proud Region," which is aligned with the learning objective: "Students recognize the diversity of national cultures in the context of pluralism." As well as the learning objective: "Through augmented reality media, students are able to interpret information about cultural heritage in their region; and through the 3D augmented reality application, students are able to design posters illustrating the characteristics of local

cultural heritage and relate them to everyday life". According to Wijajanti (as cited in Saniyyah & Triyana, 2020) The indicators of adaptive reasoning that remain low include the ability to formulate hypotheses, plan and solve problems, provide explanations related to the procedures used, evaluate the correctness of solutions, and construct answers through logical conclusions. In addition, according to Torrance (as cited in Situmorang et al., 2020) The creativity indicators—flexibility, originality, elaboration, and fluency—show that students have not yet achieved satisfactory performance in several of these areas, as evidenced by the presence of the lowest score in the class, which was 55.

In addition to selecting appropriate learning methods, another factor that influences the success of the learning process is the utilization of tools or learning resources. One such resource that can be utilized to improve the quality of the learning process is Augmented Reality (AR) as an instructional medium. This medium integrates virtual objects with physical objects through a computerized process, allowing them to appear in 3D or as if they exist in the real world in front of the user. Augmented Reality (AR), also known as enhanced reality, combines digitally created three-dimensional objects within the real environment and displays them in real time without replacing the actual surroundings, as is the case with Virtual Reality (VR) technology. The use of AR technology involves two main methods: Marker-Based Tracking and Markerless Augmented Reality. Each method has its own advantages and disadvantages. Marker-Based Tracking utilizes markers or visual cues on 3D objects to obtain information about the position and orientation of the objects. In contrast, Markerless Augmented Reality does not require the use of markers to display 3D objects; however, this method also has its own limitations (Farianto, Prasetyo & Raharja, 2021).

In this study, the method used is Marker-Based Tracking, as it plays a significant role and has proven to be more effective in the context of learning. The development of the AR application adopts the ADDIE model, which consists of five stages: Analysis, Design, Development, Implementation, and Evaluation. This method is appropriate for developing multimedia application systems and can be adapted to suit the needs of the research (Alisyafiq, Hardiyana & Dhaniawaty, 2021). During the application development process, conducting quality testing is essential to ensure that the resulting application functions properly on software platforms and effectively supports the learning development of fifth-grade students at Bulu Lor Elementary School. The quality testing focused on media validity through evaluations by three experts: media, language, and content specialists. In addition, testing was conducted with students using pretest and post-test methods to assess the extent to which the application supports student development after it is deemed feasible for use. Previous studies have shown that the use of Augmented Reality (AR) in learning can enhance students' motivation and interest, as well as improve their understanding of the concepts being studied (Airlanda, 2021). One of the studies conducted by Yulia Fatma, Armen Salim, and Regiolina Hayami at SMP Negeri 1 Benai investigated the application of AR in the science learning process. They observed that students who used AR media demonstrated improved understanding of science concepts compared to those who learned through conventional methods, which tended to feel monotonous and lacked effective explanation of the material. (Fatma, Salim & Hayami, 2021).

In contrast to previous studies that primarily focused on science learning at the junior high school level, this study centers on the IPAS subject, specifically the chapter "My Proud Region," which has rarely been explored in earlier research. Moreover, this study will conduct a quality assessment of the developed AR application using the Unity+ platform, a method that has not been widely applied in previous studies.

The aim of this study is to develop an AR application that can be used in fifth-grade elementary school learning. The AR application is expected to enhance students' interest and motivation in learning, as well as improve their adaptive reasoning and creativity skills.

Furthermore, the results of this study are also expected to improve the media's feasibility, effectiveness, and practicality, as well as to gather student response outcomes, identify the media profile, and determine its characteristics.

METHOD

His study employs the Research and Development (R&D) method, which aims to develop and validate a product. Developmental research is a primary approach for generating new innovations to be implemented and tested for product effectiveness. This method is intended to produce a product by identifying potential problems, designing, and developing the product as the most appropriate solution (Waruwu et al., 2024). This study utilizes a research and development method by applying a quasi-experimental trial design. This design was selected due to its ability to produce valid data (Abraham & Supriyati, 2022). This design involves a control group and an experimental group, both of which will be given a pretest and posttest. However, the control group will receive instruction using conventional learning media, while the experimental group will be treated with STEM-based Augmented Reality (AR) learning media.

This study employs the ADDIE model for development, resulting in STEM-based Augmented Reality (AR) learning media. The ADDIE model is an instructional design approach that is well-suited for research and development contexts. In other words, it closely resembles the process of instructional system development (Anafi et al., 2021). In line with the opinion of Hidayat & Muhamad, (2021) which states that the ADDIE model is an instructional design method focused on individualized learning. This method encompasses both immediate and long-term phases, structured systematically and employing a systems approach to understanding knowledge and human learning (Rahayu et al., 2024). The ADDIE model used in this study involves five process stages: analysis, design, development, implementation, and evaluation. These five stages are presented in Figure 1.

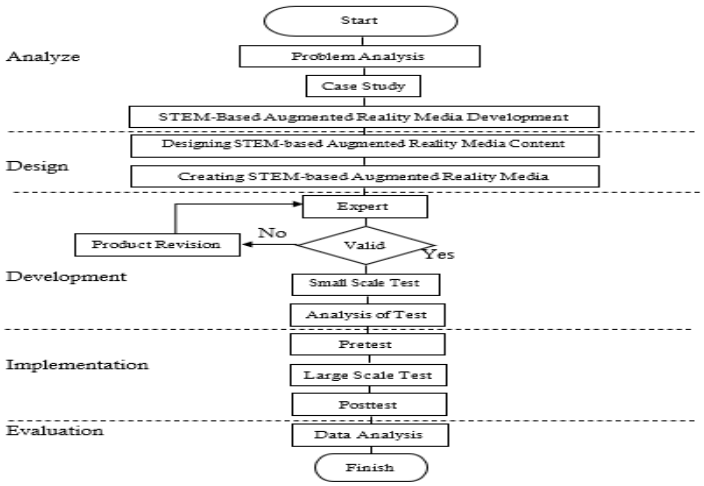


Figure 1. ADDIE Research Stages

In the analysis phase, the data sources and research subjects were fifth-grade students and classroom teachers at Bulu Lor Elementary School and Kalicari 01 Elementary School, with one school designated as the experimental class. The analysis included initial, core, and closing learning activities. This stage involved observations during the initial IPAS learning activities, followed by data collection through tests aimed at measuring students' adaptive

reasoning and creativity skills. Data collection was conducted using pretests and posttests to analyze the effectiveness of the developed STEM-based Augmented Reality (AR) learning media. The pretest was administered before the students received the treatment, while the posttest was conducted after the treatment was given. In this data collection process, a quasi-experimental trial was used, involving students, teachers, and researchers in order to obtain data related to needs analysis, feasibility, effectiveness, and the accuracy of the Augmented Reality (AR) learning media. A team of learning material validators was also involved, consisting of media, content, and language experts. The method employed utilized questionnaires as research instruments to collect data on the use of Augmented Reality (AR) media, using a Likert Scale presented in the form of a checklist. The instruments administered to students, teachers, and experts were subjected to feasibility, validity, and reliability testing to ensure their appropriateness as effective data collection tools. A good instrument must fulfill both validity and reliability requirements. Ery, E.M. 2023).

The design stage is a continuation of the analysis phase, in which the design process was visualized through a flowchart. The AR media design was created using the Canva application in a slideshow format, starting from the opening page, main menu, learning objectives, learning motivation, instructional videos, content material, project activities, quizzes, and marker integration. The subsequent phase involved the development of the AR media, which was constructed using the Unity+ application and validated by experts in media, subject content, and language to obtain constructive evaluations for refining the AR media. Validation was carried out after the media was deemed suitable for use in the learning process. The collected data were then analyzed to ensure their relevance and value. Data analysis included processing, interpretation, classification, and verification to ensure academic, social, and scientific significance. The feasibility analysis of the product was based on the results of media readability tests and expert validation. The validity of the product was obtained from questionnaires completed by media and content experts on the developed STEM-based Augmented Reality (AR) learning media.

The next stage is the implementation phase, which includes small-scale and large-scale product trials. The small-scale trial was conducted with 6 fifth-grade students at Bulu Lor Elementary School, while the large-scale trial involved 27 students in class C as the experimental group using STEM-based Augmented Reality (AR) learning media. The implementation stage involved two classes: an experimental class using STEM-based Augmented Reality (AR) media and a control class using conventional media. The purpose of this implementation was to assess the feasibility and utilization of the media in teaching the "My Proud Region" material in the IPAS subject, both before and after the media was applied. Student responses were analyzed through questionnaires administered during the product trial and usage phases. The results of the validation questionnaires were presented using a predetermined scoring scale. The effectiveness of the product was assessed through IPAS subject test items administered during the augmented reality (AR) media trial.

The final stage is the Evaluation phase. Evaluation is conducted to improve the STEM-based Augmented Reality (AR) media based on feedback from experts, teachers, and field trials. The evaluation also includes analysis of the improvement in students' adaptive reasoning and creativity skills by comparing pretest and posttest scores using the normalized N-Gain test. Ery, E.M. 2023). Normality tests were conducted to determine whether the pretest and posttest data were normally distributed. This testing was performed before and after the use of STEM-based Augmented Reality (AR) learning media, using SPSS version 2.5 as the analytical tool. Homogeneity testing was conducted to determine whether the samples had equal variances or did not differ significantly. This test employed the test of variance on the score distributions of each group. Based on the results of normality and homogeneity tests, parametric statistics were

used with independent t-tests and paired sample t-tests. This analysis aims to determine the difference in the actualization of character values between the experimental class that received the treatment and the control class that did not.

RESULTS AND DISCUSSION

The profile of the learning media is structured in the form of a prototype as the initial design that serves as a reference for further development, with the expectation that it will evolve into an interactive medium with educational content (Ottoboni *et al.,* 2020). he STEM-based AR media prototype for the theme "My Proud Region" consists of several frames, including the main menu, core material, 3D AR display, quizzes, and markers to generate AR barcodes. This system utilizes Marker-Based Tracking technology, which uses images as markers to construct virtual reality. The AR media display is presented in Figure 2.

Figure 2 Initial Page Frame of the Application

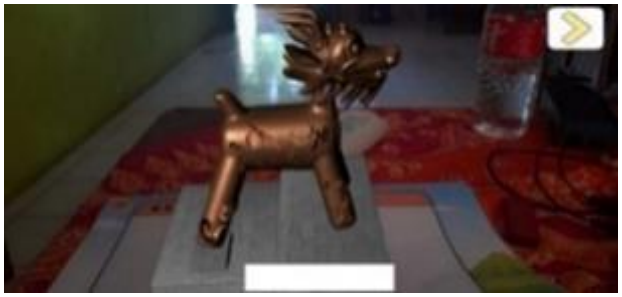


Figure 3 3D Frame of Warak Ngendog

Figure 4 *3D* Barcode Frame of Warak Ngendog

Figure 5 Frame of AR Tugu Muda

Figure 6 Frame 3D Barcode From of Tugu Muda

Figure 13 Frame of Quiz

The characteristics of the STEM-based AR instructional media development are designed to align with the learning objectives, particularly for the topic "My Proud Region" in Grade V. This media is characterized as interactive, effective, versatile, simple, affordable, and user-friendly. The learning material is adapted to the characteristics of the students, encompassing explanations of cultural acculturation and cultural heritage in the city of Semarang, complemented by engaging 3D visualizations. Utilizing the STEM learning model, this media integrates science, technology, engineering, and mathematics. A multiple-choice quiz is provided, offering immediate feedback in the form of scores and answer reviews. The application is accessible via mobile phones, can be downloaded from Google Drive, and is operable offline once installed.

The feasibility of the AR media includes a validation process conducted by experts to ensure its appropriateness and validity. This validation involves evaluations by media, content, and language experts, each carried out by competent individuals in their respective fields. Suggestions from the validators, such as the use of pivot input, are considered for further development. The scores provided by experts, teachers, and students are averaged to obtain the overall percentage, which is presented in Table 1.

Table 1. Scores and Criteria of Content Validation Results

Assessment Indicators	Number of Items	Score
Relevance of the Material to the Indicators and Learning Objectives	7	33
Learning Presentation	3	15
Content Completeness	5	24
Total Score Obtained		72
Maximum Total Score		75
Percentage		96%
Validity Criteria		Highly Valid

Based on the results of the content expert validation, a validity percentage of 96% was obtained, which falls into the "Highly Valid" category and meets the eligibility criteria for the content aspect. Subsequently, the media was validated by competent parties in the field of media to ensure the product's validity and to obtain feedback for improvement. The overall score percentage and criteria are presented in Table 2.

Table 2. Scores and Criteria of Media Validation Results

Assessment Indicators	Number of Items	Score
Layout	6	28
Typography	6	28
Color	6	27
Images and Animations	5	22
Total Score Obtained		105
Maximum Total Score		115
Percentage		91%
Validity Criteria		Highly Valid

Based on the results of the media expert validation, a validity percentage of 91% was obtained, which is categorized as "Highly Valid." Subsequently, validation was conducted by a language expert to ensure the linguistic validity

and to obtain suggestions for improvement. The results are presented in Table 3.

Table 3. Scores and Criteria of Language Validation Results.

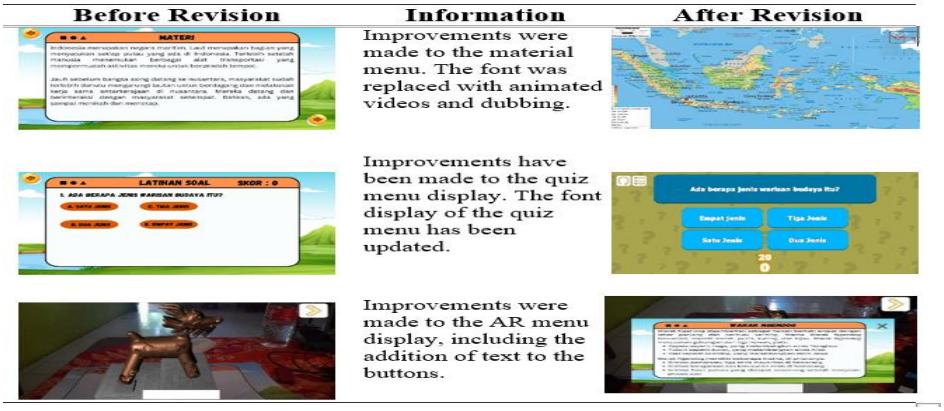
Assessment Indicators	Number of Items	Score
Conformity with Indonesian Language Rules	8	37
Correct Use of Punctuation	2	10
Total Score Obtained		47
Maximum Total Score		50
Percentage		94%
Validity Criteria		Valid

Based on the results of the language expert validation, a percentage of 94% was obtained, which falls into the "Valid" category, indicating that the media is deemed suitable for use. The research findings may be presented with the support of tables, charts, or figures as needed, to enhance the clarity of the verbal presentation of results. After the expert validators provided their assessments, the scores from each expert were then combined using the Aiken's V formula. Displays the assessment categories, starting from I to VI (possible assessors or assessment aspects), then S1 to S6 (indicators or sub-aspects), and followed by the symbols Σ (total number), n(c-1) (reliability/validity calculation formula), V (validation value), and description. This graph illustrates a summary of the learning media validation results from several assessors and aspects. The value in the Σ section represents the total score, while n(c-1) is used in calculating the validity index (e.g., using Aiken's V). The assessment results of 15 test items by six expert validators, teachers, and six evaluation subjects indicate that the Aiken's V validity values for each item range from 0.91667 to 1, which fall into the "Very High" category. This demonstrates that all test items possess excellent validity and are appropriate for use.

Furthermore, the results of the product practicality assessment involved responses from both teachers and students. A total of 3 teachers and 9 fifth-grade students from Class V A at SD N Bulu Lor participated in learning activities using the STEM-based AR media. Based on the practicality assessment questionnaire completed by the teachers, a percentage score of 97% was obtained, indicating the category of "Very Good." Additionally, a summary of the product practicality questionnaire results from the 9 student respondents is also presented.

Based on the practicality questionnaire completed by 9 students, a percentage score of 82% was obtained, which falls into the "Good" category. This indicates that the learning media is considered practical and feasible for use.

Subsequently, revisions to the STEM-based AR media involved improvements, suggestions, and input from experts in media, content, and language in order to refine the media. The results of the text revision are presented in Figure 13.



Based on suggestions from language, media, and content experts, the improvements to the STEM-based AR media included the use of animated videos and voice dubbing in the material menu, enhancement of text brightness in the quiz menu, and the addition of text on the central button in the AR menu.

The effectiveness of the STEM-based AR learning media was evaluated through research involving 100 fifth-grade students. Of these, 28 students from class VA served as the experimental group using the STEM-based augmented reality (AR) learning media, while 72 students from classes VB, VC, and one class from SDN Kalicari 01 constituted the control group using conventional learning media. The effectiveness of the AR media was measured through pretest and posttest consisting of 15 items designed to assess the improvement of students' adaptive reasoning and creativity. The results were analyzed to determine the impact of AR media usage, in line with the findings of Widiastika et al. (2021), which state that Android-based media can enhance learning quality and increase students' motivation.

The results of data analysis using validity testing for the adaptive reasoning questionnaire were processed with SPSS using the Pearson formula. A total of 15 items were declared valid, covering five indicators of adaptive reasoning: formulating conjectures, planning and solving problems, explaining procedures, evaluating the correctness of answers, and drawing conclusions. The test items met the validity criteria and were deemed appropriate for measuring students' abilities. Meanwhile, of the 15 creativity questionnaire items that were tested, five were found to be invalid and thus could not be used.

The results of data analysis through the validity test of the creativity questionnaire using SPSS with the Pearson formula showed that out of 20 creativity questionnaire items tested, most were declared valid. These items reflected indicators including flexibility, originality, elaboration, and fluency, making them suitable for assessing students' creativity. However, five items were found to be invalid and therefore could not be used.

Reliability analysis using SPSS with the Cronbach's Alpha formula on 20 validated questionnaire items showed that all items had r_calculated values greater than r_table (1.989319). This indicates that all items met both validity and reliability criteria, making them appropriate for use without revision in measuring students' abilities according to the learning indicators.

The results of the normality test for the posttest data of fifth-grade students using the Shapiro-Wilk test through SPSS showed that the p-value for the experimental class was 0.083 and for the control class was 0.087. Since both values are greater than $\alpha = 0.05$, H_0 is accepted. Therefore, it can be concluded that the posttest data of both classes are normally distributed at a 95% confidence level.

The results of the homogeneity test showed a p-value of 0.023. Since the p-value > $\alpha = 0.05$, H_0 is accepted, indicating that at a 95% confidence level, the posttest data of the experimental and control classes have homogeneous variances.

The results of the hypothesis test using SPSS 26 indicated that the tcount value (5.825) > ttable (0.344) and the significance value (0.000) < α (0.05). These results demonstrate a significant effect of the use of STEM-based augmented reality learning media on students' adaptive reasoning and creativity skills.

The results of the N-Gain test showed a mean score of 55.8475 categorized as "moderate" and a mean posttest score of 72.7541 categorized as "high". These findings indicate a significant improvement in learning outcomes in the experimental class after the implementation of STEM-based augmented reality (AR) learning media.

The data from students' pretest and posttest results on creativity are presented in a diagram and can be seen in Figure 13.

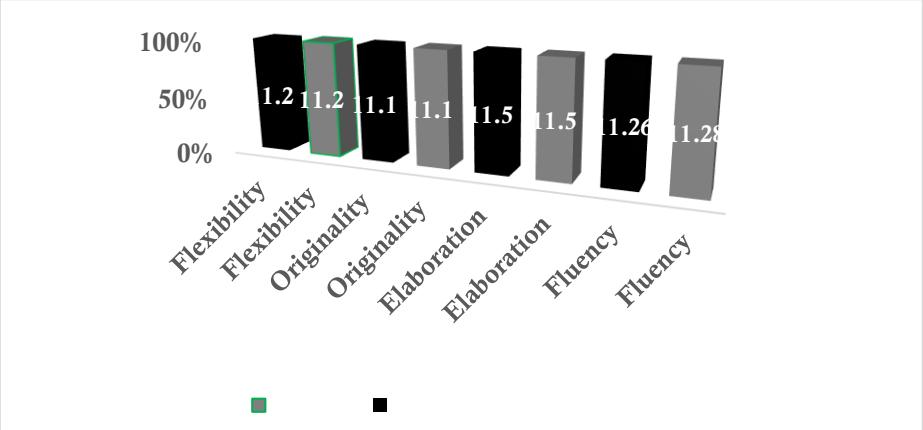


Figure 13. Pretest and Posttest Results on Creativity

The results of the students' creativity pretest prior to using the AR media showed varying average scores across each indicator: flexibility 11.22, originality 11.1, elaboration 11.5, and fluency 11.26. The highest score was found in the elaboration indicator, while the lowest was in originality. After the learning process using AR media, the posttest results showed relatively stable average scores for each indicator: flexibility 11.22, originality 11.1, elaboration 11.5, and an increase in fluency to 11.28. The fluency indicator showed an improvement, while the others remained stable. The analysis was conducted using the N-Gain mean difference test.

The data from the students' pretest and posttest results on adaptive reasoning are presented in a diagram and can be seen in Figure 14.

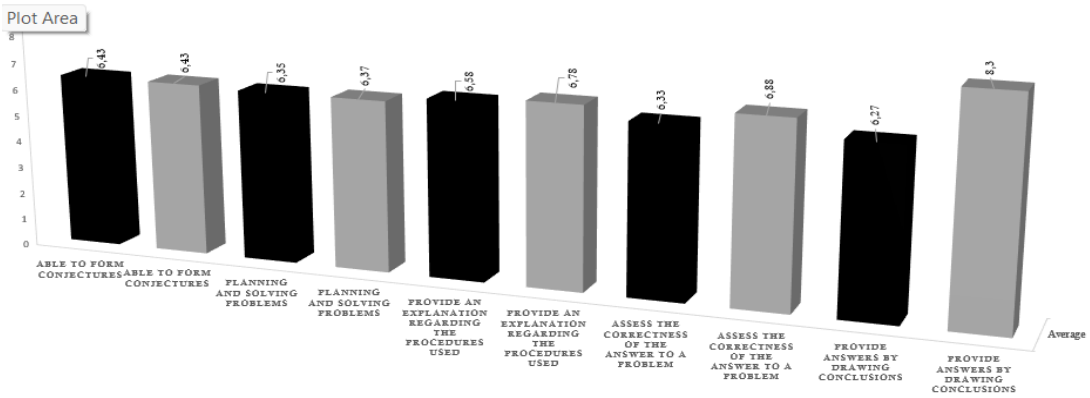


Figure 14. Pretest and Posttest Results on Adaptive Reasoning

The results of the pretest on students' adaptive reasoning prior to learning with AR media showed variations in the average scores across each indicator. The highest score was found in the indicator "providing explanations related to the procedures used" (6.58), while the lowest score was in the indicator "providing answers through drawing conclusions" (6.27). Overall, students' adaptive reasoning abilities were still considered low and uneven across all indicators. he results of the posttest on students' adaptive reasoning after learning with AR media showed an increase in the average scores across most indicators. The indicator "providing answers through drawing conclusions" demonstrated the highest improvement with a

score of 8.3, while the indicator "formulating conjectures" remained stable at 6.43. Improvements were also observed in the indicators of planning and solving problems, explaining procedures, and evaluating the correctness of answers. The data were analyzed using the N-Gain test to examine the differences in mean scores.

CONCLUSION

Based on the research findings, it can be concluded that the STEM-based augmented reality (AR) learning media developed using Unity+ and Canva successfully produced an application accessible via mobile phones and laptops. This media was proven to be highly valid based on validation results from media, language, and content experts, with scores exceeding 90%. In addition to being feasible, this media was also effective in enhancing the adaptive reasoning and creativity skills of elementary school students, as evidenced by the N-Gain test results and the significant differences between the experimental and control classes. For creativity, the posttest scores show consistent increases across all indicators—fluency, flexibility, originality, and elaboration—with the most notable gain observed in the fluency indicator. This suggests that students became more capable of generating ideas smoothly and efficiently after using the AR media. In terms of adaptive reasoning, the posttest results also reflect an upward trend across key indicators, including formulating conjectures, planning and solving problems, explaining procedures, evaluating answer accuracy, and drawing conclusions. The most substantial improvement was seen in the indicator "drawing conclusions," highlighting the media's effectiveness in enhancing higher-order thinking.

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