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Development of AURASTRA Interactive Multimedia to Improve Students' Critical Thinking Skills

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Abstract: This study aimed to develop and evaluate the feasibility, practicality, and effectiveness of AURASTRA Interactive Multimedia based on Augmented Reality (AR) to enhance sixth-grade elementary students' critical thinking skills in learning the Solar System topic within the IPAS curriculum. The research employed a modified Research and Development (R&D) approach using the Four-D model (define, design, develop, and disseminate). The feasibility of the product was validated by media and subject-matter experts, yielding scores of 89.5% and 87.6%, respectively, indicating a highly feasible category. Practicality testing through student response questionnaires involving 20 students resulted in a score of 96.75%, demonstrating that the multimedia was highly practical, engaging, and user-friendly. Effectiveness testing revealed that the experimental group achieved a higher post-test mean score (86.2; SD = 5.5) compared to the control group (80.4; SD = 7.94). The N-gain analysis showed a great improvement in the experimental class (0.76) and a moderate improvement in the control class (0.62), indicating a significant enhancement in students' critical thinking skills. These findings confirm that AURASTRA Interactive Multimedia is feasible, practical, and effective for supporting science learning and fostering critical thinking skills in elementary education. The integration of AR technology provides immersive and interactive learning experiences that facilitate conceptual understanding and higher-order thinking development.

Keywords: Interactive Multimedia, AURASTRA, Augmented Reality, Critical Thinking, Solar System.

1. Introduction

Science and Social Studies (IPAS) instruction under the Merdeka Curriculum aims to cultivate scientific literacy, higher-order thinking skills, and 21st-century competencies by engaging students in contextual and meaningful learning experiences. Within Phase C of elementary education, the solar system is a foundational topic that encompasses abstract concepts such as planetary rotation, revolution, orbital mechanics, and the gravitational forces that govern celestial interactions. These concepts are inherently difficult for young learners to visualize with traditional two-dimensional texts or teacher-centered explanations, which often leads to misconceptions and a superficial understanding of scientific phenomena.

Instructional media are critical for mediating complex scientific concepts and facilitating students' cognitive engagement. Contemporary theory emphasises that effective learning media should not merely present information but should actively support conceptual construction and cognitive processes (e.g., multimedia learning theory). Digital technologies, particularly interactive multimedia, have transformed learning by integrating text, visuals, animations, and interactive elements that elicit active learner participation. The integration of technology into pedagogy through frameworks such as Technological Pedagogical Content Knowledge (TPACK) highlights that instructional tools must not only support content delivery but also enhance pedagogical processes that foster critical thinking and problem solving.

Critical thinking is a core competency in science education that encompasses the abilities to interpret evidence, analyse relationships, evaluate arguments, draw reasoned inferences, and reflect upon reasoning outcomes. According to foundational consensus on critical thinking by Facione and colleagues, critical thinking involves disciplined evaluative and inferential processes essential for academic reasoning across disciplines. These skills are especially important in topics like the solar system, where students must analyse cause-effect relationships (e.g., rotation versus day–night cycles) and evaluate evidence for astronomical phenomena. However, conventional classroom practices in primary education tend to prioritise rote memorisation and fact recall over authentic inquiry, thereby limiting opportunities for systematic development of critical thinking skills.

Despite the theoretical potential of digital media, there remains a gap between the capabilities of emerging technologies and their application in classrooms. Augmented reality (AR) offers immersive visualisation that overlays virtual 3D objects onto real environments, enabling learners to interact with abstract concepts in a tangible format. Systematic reviews and meta-analyses of AR in science education indicate that AR can enhance conceptual understanding, engagement, and critical thinking when embedded within pedagogical designs that promote active learning and reflective inquiry. Specifically, bibliometric trends show that AR research in elementary science education is growing. Yet, implementation studies that emphasise critical thinking outcomes remain limited relative to studies on general learning improvement or motivation (Indahsari & Sumirat, 2023).

Empirical studies at the primary level have reported that AR-supported science media can improve students' conceptual understanding and performance in critical thinking. For example, AR-based science games and interactive applications were found to significantly elevate learners' science literacy and critical reasoning compared to pre-intervention levels (Najib et al., 2023). Moreover, research in solar system learning contexts has shown that AR can make abstract astronomical concepts accessible through interactive visualization, though many of these implementations focus primarily on conceptual gains rather than structured critical thinking development (Hidayat, 2024).

In addition to practical gaps, a theoretical gap persists between the design of AR learning tools and current pedagogical frameworks. Constructivist theory emphasises that meaningful learning occurs when students engage in exploration, hypothesis testing, and reflection. Likewise, inquiry-based and problem-based learning models align with the goals of critical thinking development by encouraging learners to pose questions, investigate phenomena, and justify conclusions. However, many AR applications in elementary education have been designed without intentional integration of these constructivist elements, resulting in tools that visualise content without explicitly scaffolding cognitive processes related to analysis, evaluation, and reflection—a limitation highlighted in both AR and science education research.

From an empirical research perspective, studies on AR and critical thinking in elementary science have reported positive trends but also notable limitations. While some AR developments have demonstrated effective learning improvements and positive student responses, the majority do not systematically measure critical thinking using well-defined indicators (e.g., interpretation, analysis, evaluation). Additionally, most studies focus on isolated interventions rather than integrated multimedia systems that unify AR features with structured instructional sequences aligned to curriculum standards. As a result, there is a clear need for research that develops and assesses AR-enhanced learning media designed to foster critical thinking through guided inquiry and reflective activities.

This study responds to these gaps by developing AURASTRA (Augmented Reality Solar System Interactive Multimedia)—an integrated learning environment that combines marker-based AR visualisation, structured instructional modules, inquiry-driven tasks, and assessment components aligned with critical thinking indicators. Grounded in constructivist pedagogy and the TPACK framework, AURASTRA aims to transform abstract concepts into interactive, student-centred experiences that stimulate analysis, reasoning, and reflection. The novelty of this research lies in its systematic integration of AR technology with pedagogically aligned tasks, explicit scaffolding of critical thinking processes, and alignment with Phase C learning outcomes under the Merdeka Curriculum.

By bridging the gap between technological potential and pedagogical design, this research contributes both theoretically—to understanding how AR can support critical thinking within science learning—and empirically—to improving instructional practice for elementary students learning about the solar system.

2. Methodology

The type of research used in this study is development research, also known as Research & Development (R&D). Development research is a research method that produces a developed product, which is then tested for effectiveness (Sugiyono, 2015: 407). The AURASTRA interactive multimedia development procedure follows the flow described by Thiagarajan, et al. (1974: 5), namely the Four-D model, which includes Define, Design, Development, and Dissemination. The reasons for using the Four-D model are the interactive multimedia development sequence is more detailed and the validation and testing stages result in a better/more perfect final draft of the interactive multimedia. The main steps in the research are not only applied according to the original version but are also adapted to the needs of development in the field.

2.1 Research Design

This study uses the Four-D Research and Development (R&D) model (Thiagarajan, 1974), which aims to develop and evaluate an interactive multimedia called AURASTRA for elementary school students in teaching Natural and Social Sciences (IPAS). The development process follows the Four-D model, which is widely applied in educational product development due to its systematic structure, allowing for continuous revision based on expert assessment and field testing.

Recent studies confirm that R&D design is effective in producing digital learning media that is valid, practical, and effective in the context of basic education (Damayanti et al., 2022). Due to time and resource constraints, the development stages were adapted and implemented until the product was revised after field testing, which was considered sufficient to evaluate the feasibility, practicality, and effectiveness in educational R&D studies (Albani, 2024).

Participants and Research Setting. The study was conducted in public elementary schools in Pati Regency, Central Java, Indonesia. Participants consisted as in Table 1:

Table 1: **Research data expert background and expertise.**

Respondent	Background
R1	20 elementary school students in the experimental group
R2	20 elementary school students in the control group
R3	25 elementary school students limited product testing

Sampling was carried out using simple random sampling, as the population was homogeneous with parallel classes. This sampling technique is recommended for experimental studies to reduce selection bias and ensure internal validity Creswell, (2017).

2.2 Development Procedure

The development of AURASTRA followed these main stages and displayed in Fig. 1 and Fig.2 :

a. Needs Analysis, conducted through classroom observation, interviews with teachers, and student questionnaires to identify learning difficulties and critical thinking problems.

b. Product Design, involving the development of solar system content using the Unity 3D application.

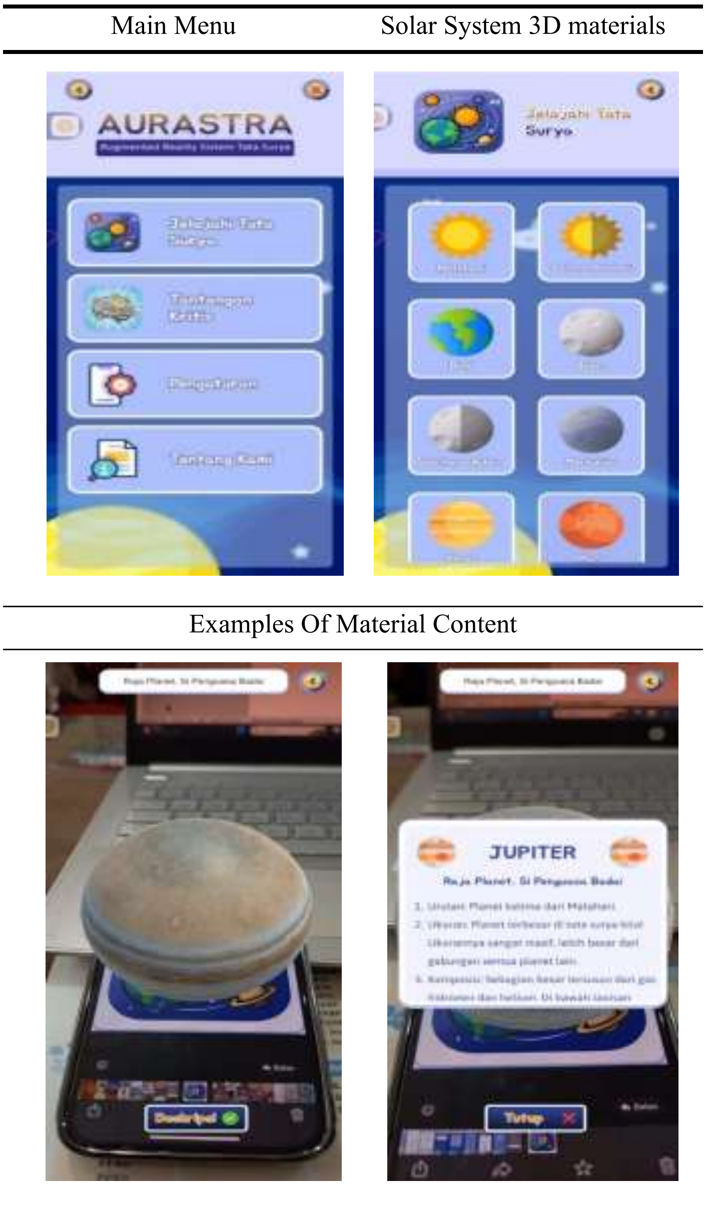

Figure 1: Design of AURASTRA interactive multimedia displaying 3D images of planets in the solar system.

c. Expert Validation, including material experts, media experts, and assessment experts to evaluate content accuracy, instructional design, usability, and assessment quality.
d. Limited Field Testing, conducted to assess practicality and user responses.
e. Main Field Testing, employing a quasi-experimental design to evaluate effectiveness.
f. Product Revision, based on quantitative and qualitative feedback from field testing.

Quiz Menu

Examples Of Quiz Content

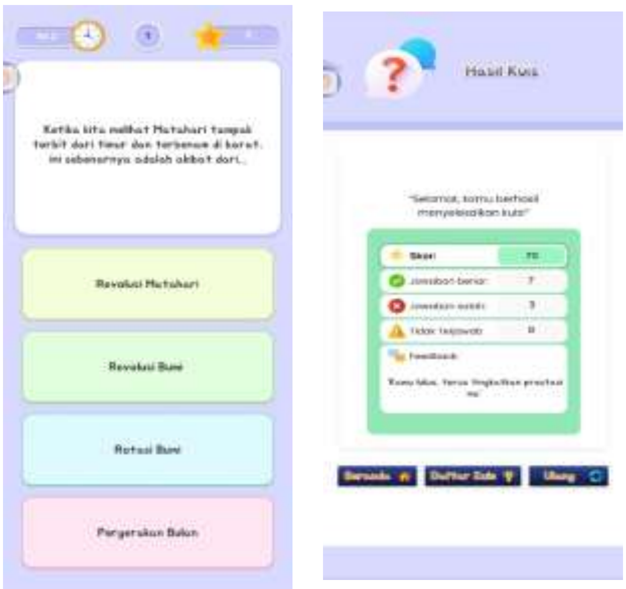

Figure 2: Critical thinking features in the form of quizzes to measure critical thinking skills

This staged approach aligns with best practices in instructional media development research Tegeh et al., (2014); Firdaus et al., (2025).

2.3 Instruments and Data Collection

Data were collected using test and non-test techniques:
a. Learning Achievement Tests.
Pretest and posttest instruments consisting of 25 multiple-choice items were developed based on Bloom's taxonomy to measure students' critical thinking skills of the solar system.
b. Questionnaires
1) Needs analysis questionnaires for teachers and students.

2) Media feasibility questionnaires for expert validation
3) Practicality questionnaires for teacher and student responses

c. Observation Sheets

Critical thinking skills are one of the 21st century skills that students must master, so it is hoped that in learning activities, teachers will accustom students to think critically.

d. Interviews and Documentation

Semi-structured interviews with teachers and documentation of learning activities supported qualitative data triangulation.

2.4 Data Analysis

Data were analyzed using quantitative and qualitative descriptive techniques:

a. Analysis was conducted using expert validation scores converted into percentages and interpreted using established feasibility criteria.
b. Effectiveness Analysis involved:
   1) Independent sample t-tests to examine differences between experimental and control groups.
   2) N-gain analysis to determine learning improvement.
   3) Effect size (Cohen's d) to measure the magnitude of AURASTRA's impact on critical thinking skills.
c. Encouraging students to analyze, evaluate, and synthesize information, rather than simply memorizing it, thereby facilitating data collection and analysis of students' critical thinking skills.

Effect size interpretation followed Cohen's standardized criteria, which are widely accepted in educational research for reporting practical significance (Albani, 2024).

2.5 Ethical Considerations

All participants were involved voluntarily with approval from the school authorities. Students' identities were anonymized, and data were used solely for research purposes, in accordance with ethical standards for educational research Creswell (2017).

3. Results and Discussion

This section reports the findings obtained from both test and non-test data collection techniques. Non-test data were gathered through classroom observations, teacher and student response questionnaires, documentation, and interviews. Classroom observations were conducted to identify initial learning conditions and to assess students' digital literacy and process skills during instructional activities. Questionnaires were administered to examine teachers' and students' responses to the developed learning media, particularly their practicality and usability. Interviews were carried out to complement the needs analysis by exploring instructional challenges and expectations regarding learning media. Test data were collected using multiple-choice items administered to elementary school students. Before implementation, the test items were analyzed for validity, reliability, difficulty level, and discrimination index. The results indicated that the instruments met acceptable measurement standards. Data from various sources were triangulated to enhance the robustness of the findings. Overall, these results provide empirical support for evaluating the effectiveness and practicality of the developed learning media.

3.1 Product Development and Validation Results

The AURASTRA interactive multimedia was developed through a systematic Research and Development (R&D) process adapted from the Four-D model. Expert validation results indicate that AURASTRA interactive multimedia meets high feasibility standards for instructional use as in Table 2.

Table 2: Expert validation results of EBACSIS

Validator	Aspect Evaluated	Mean Score (%)	Category
Material Experts	Content accuracy, clarity, relevance	87.6	Very Feasible
Media Experts	Layout, visual design, usability	89.5	Very Feasible

These results demonstrate that AURASTRA satisfies pedagogical, visual, and assessment quality criteria and is suitable for classroom implementation on solar system material.

3.1.1 Practicality of AURASTRA

Practicality was evaluated through a small-group trial involving teachers and students. Table 3 illustrated user responses indicate a high level of usability and accessibility.

Table 3: Practicality test results

Respondent	Practicality Score (%)	Interpretation
Students	96.75	Very Practical
Teachers	100	Very Practical

Minor technical feedback to enhance the material on lunar and solar eclipses in the form of 3D content to broaden students' understanding of the solar system.

3.1.2 Effectiveness on critical thinking skill

The effectiveness of AURASTRA was tested using a quasi-experimental design comparing an experimental group (using AURASTRA) and a control group (conventional learning) as in Table 4.

Table 4: Comparison of Learning Outcomes

Group	Mean Pretest	Mean Posttest	N-Gain	Category
Experimental	39.4	86.2	0.76	High
Control	43.2	80.4	0.62	Moderate

The Sig. (2-tailed) value is $0.007 < 0.05$, which indicates that there is a difference between the experimental class and the control class. There is a difference in post-test learning outcomes between the control and experimental classes, namely that the post-test learning outcomes in the experimental class are higher than those in the control class. Thus, it can be said that the AURASTRA interactive multimedia for the IPAS subject on the solar system is effective in improving critical thinking skills.

4. Conclusion

Based on the results of the development research, presentation, and discussion described above, it can be concluded that the feasibility of AURASTRA interactive multimedia (Augmented Reality Solar System Material) for the IPAS (Natural and Social Sciences) subject on the solar system is very feasible for use in learning activities, with an average expert validation percentage of: media experts 90.75%, material experts 94% with a category of “very feasible”. This is in line with research conducted by Tresnawati et al. (2021), which states that learning media using Augmented Reality are very feasible for improving student learning outcomes. This is also in line with the research by Mutmainah & Purwowidodo (2024) that interactive multimedia based on Augmented Reality is very suitable for learning.

AURASTRA is also considered practical for use in learning activities. The results of the student response questionnaire show a total score of 774 across 20 participating students. After conversion into a percentage, a value of 96.75% was obtained, indicating that AURASTRA is also considered practical and interesting by students. Thus, both teachers and students responded positively to the use of AURASTRA Interactive Multimedia, making this media suitable for use in the learning process in elementary schools. This is in line with the results of research conducted by Sukma et al., (2023) that the use of augmented reality learning media using mobile phones (Android) is very practical because students use them every day, making it easier for them to access them. Another relevant study is the research conducted by Rakhmat (2020), which states that augmented reality media is suitable for learning in primary schools, especially for abstract material such as the solar system.

In addition, AURASTRA was declared effective for use in learning. The average pretest results for the control class and the experimental class were 41.3 with a standard deviation of 14.0. The average post-test for the experimental class was 86.2 with a standard deviation of 5.5. Meanwhile, the average post-test for the control class was 80.4 with a standard deviation of 7.94. This means that there is a difference in posttest learning outcomes between the control and experimental classes, namely that the posttest learning outcomes in the experimental class are higher than those in the control class. The N-gain test results for the experimental class were 0.76 in the high category, while those for the control class were 0.62 in the medium category. Thus, learning using AURASTRA Interactive Multimedia is classified as effective. Research conducted by Fujiyati et al., (2024) shows that Augmented Reality learning media applied in learning shows a significant increase in student learning outcomes. This improvement occurs because Augmented Reality is able to present visualisations of objects in a realistic and interactive manner, thereby helping students to understand abstract material. Another study supporting this statement is the research by Riskiono et al. (2020), which found that Augmented Reality-based learning media can enhance students' understanding and critical thinking skills.

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