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Development of *AstroMotion* Media to Improve Students' Critical Thinking Skills in Natural Science Learning

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ABSTRACT

This study aims to develop *AstroMotion* media that are valid, practical, and effective in improving students' critical thinking skills in Natural Science learning. The method used in this study was Research and Development (R&D) employing the ADDIE development model, which includes the stages of Analysis, Design, Development, Implementation, and Evaluation. The research subjects consisted of 24 sixth-grade students at MIS Al-Barkah. The research instruments included validation questionnaires, practicality questionnaires, as well as pre-test and post-test questions. The validation results show that the media is rated as very valid by media experts based on physical aspects, usability, illustrations, color, and images, with a score of 89.4%, and by material experts with a score of 90%. The practicality of the media, based on student responses, is 88.43%, and from the teacher, it is 90%, both categorized as very practical. Data analysis using the N-gain formula shows an increase in the average score from 57.7 to 87.7, with an N-gain score of 0.71, which is classified in the high category. Therefore, *AstroMotion* media is proven to be effective and suitable for use as a learning tool in Natural Science to improve students' critical thinking skills.

Keywords: development, *AstroMotion*, critical thinking, natural science

INTRODUCTION

The PISA (Programme for International Student Assessment) report indicates that Indonesian students' performance in science is below the international average, suggesting that they lack the critical thinking skills needed to understand science in depth[1]. Science is a form of critical thinking that arises from human curiosity about the environment and the desire to understand, control, and utilize it according to our needs[2]. Critical thinking is an intellectual process that involves the conceptualization, application, integration, and evaluation of information obtained through observation, experience, reflection, reasoning, or communication, which is then used as the basis for forming beliefs and making decisions or taking action[3]. Therefore, critical thinking skills are essential in the learning process. With the rapid development of technology, every student is required to possess critical thinking skills to face the various changes that occur[4].

Critical thinking skills are among the essential skills in problem-solving [5]. Teaching that emphasizes critical thinking has several benefits, including increasing the effectiveness of the learning process because students are more likely to remember the material. Furthermore, this approach can enhance their engagement and enthusiasm in learning. Through critical thinking skills, students are expected to develop scientific reasoning and problem-solving abilities, both in the learning process and when facing real-life challenges[6]. There are 12 indicators of critical thinking, grouped into five main activities: providing simple explanations, building basic skills, summarizing, providing further explanations, and setting strategies and methods[7].

Science plays an important role in the field of education because it can shape students' critical and analytical thinking patterns and prepare them with the skills needed to understand and solve various problems in daily life[8]. The objective of Natural Science learning is to develop students' curiosity, enhance their ability to ask questions and find answers based on evidence, and refine their scientific thinking skills[9]. Students not only focus on conceptual understanding, but also have the opportunity to participate in the product development process directly, develop scientific insight, and, more broadly, acquire scientific literacy[10]. However, in practice, Natural Science learning is still often conducted using traditional methods, namely through lectures and static media such as images and texts in books, which tend to be passive and do not sufficiently encourage students to think critically[11].

Based on the preliminary observations conducted by the researcher in the sixth-grade class at MIS Al-Barkah, the development of students' critical thinking

skills has not been optimal. This is evident from the learning method that remains teacher-centered and uses only textbooks as teaching tools. The limitations in capacity and the availability of instructional media infrastructure have caused students to learn more material theoretically rather than through direct experience. This condition results in students not yet optimally understanding the material presented and being less able to use their own words to draw conclusions and explain the concepts learned. This illustrates the importance of critical thinking skills for students. However, in reality, many students still lack critical thinking skills[12]. Therefore, the use of instructional media plays a very important role in the teaching of scientific material about the solar system.

Several previous studies have investigated the development of teaching materials on the topic of the solar system and have demonstrated a variety of tools used to support the learning process. A study conducted by[13] used a pop-up book as a visual tool to teach the solar system to sixth-grade elementary school students.[14] This study examined the use of digital media based on augmented reality, which was developed with input from content and media experts and practically tested by teachers and students. In addition, this study[15] developed PASITAYA media (Solar System Board), which was designed for use in science subjects and received positive responses from various stakeholders. These three studies indicate that innovative and interactive media have the potential to enhance student engagement and understanding of learning materials, particularly on the topic of the solar system.

The above explanation shows that educational media are used as a means of delivering learning materials so that students can better understand the lessons and broaden their knowledge to achieve the learning objectives[16]. A monotonous teaching style may cause boredom among students. Therefore, teachers need to innovate in the teaching process and provide teaching tools that can help students learn the material more easily and achieve the learning objectives as effectively as possible. It is important that teachers not only study the material, but also can adjust their teaching methods and understand students holistically [17]. In this regard, the method used must be able to stimulate students' interest and enjoyment in the learning process[18]. Although solar system media have been widely used in science disciplines to develop students' critical thinking skills, their use remains limited. The distinctive feature of this study lies in its focus on developing elementary school students' critical thinking skills using a specially designed instructional medium, namely *AstroMotion* media.

AstroMotion is a medium that utilizes motion visualization to illustrate phenomena within the solar system. In the context of education or instructional materials, the term "*Astro*" is commonly used to describe topics or tools related to astronomy (the study of celestial bodies) or the solar system. Meanwhile, the term "*Motion*" refers to the movement of objects within the solar system, which is visualized using dynamic media such as simulations to enhance the understanding of astronomical concepts.

Various learning theories emphasize the importance of using media in education, particularly to enhance the understanding of abstract concepts. Constructivism in learning is a process that encourages students to actively construct new concepts, new ideas, and new knowledge based on data[19]. According to the constructivist theory in[20], the theory developed by Piaget and Vygotsky emphasizes the importance of direct experience and social interaction in the learning process. In the context of learning about science, particularly the solar system, this theory emphasizes that students must actively construct their own understanding through rich experiences and interactions[21]. One of the methods that teachers need to implement is the use of media that supports the learning process[22].

Based on the above background, the objective of this study is to develop *AstroMotion* media that is valid, practical, and effective in improving students' critical thinking skills in Natural Science learning. It is expected that the results of this study can make a tangible contribution to the field of education, particularly in the development of instructional media that supports the enhancement of students' critical thinking skills. In addition, this study also plays an important role in assisting teachers and students in achieving learning objectives that align with the current curriculum.

RESEARCH METHOD

This type of research was development research or Research and Development (R&D), which referred to a process or set of steps conducted to develop a new product or improve an existing one[23]. The ADDIE model was used in this development research, which consisted of five stages: analysis, design, development, implementation, and evaluation. The ADDIE model was recognized as a systematic approach for developing structured and effective training programs[24].

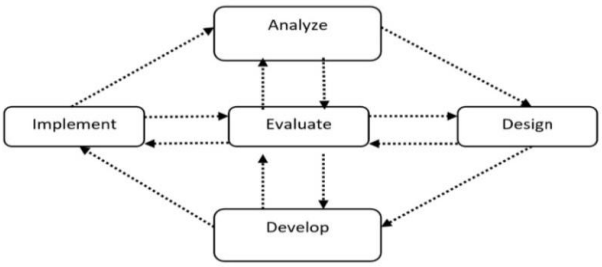

Figure 1. Stages of the ADDIE Model

The research subjects were sixth-grade students at MIS Al-Barkah in the 2024/2025 academic year, with a sample size of 24 students. The data sources in this study consisted of primary data obtained through questionnaires and test results, and secondary data obtained from student enrollment records and class schedules. The instruments used in this study included expert validation sheets (media and content), teacher and student response questionnaires, and critical thinking tests in the form of essay questions developed based on critical thinking skill indicators by Ennis to measure the effectiveness of the media[25]. Data collection methods included questionnaires, tests, documentation, and observation.

The data analysis techniques in this study included the analysis of validity, practicality, and effectiveness. The descriptions of the data analysis are as follows.

1. Feasibility Analysis Technique

A feasibility analysis was conducted to assess the feasibility of the *AstroMotion* media based on the questionnaire results completed by media experts and content experts. The validators were asked to evaluate each available aspect by selecting one of the rating categories: very good, good, fair, poor, and very poor. The assessment was carried out by checking the appropriate score on the questionnaire sheet.

The formula used to calculate the average score of the review results from media and content experts is as follows[26]:

$$P = \frac{\sum x}{\sum xi} \times 100\%$$

Description:
P : Feasibility percentage
∑x : Total score of the assessment responses
∑xi : Maximum possible total score

To support the verification data obtained from media and content experts, a standard rating reference table of average scores was used as follows:

Table 1. Media and Content Validity Assessment Guidelines[27]

Score Range (%)	Assessment Category	Description
81 – 100	Very Feasible	Feasible for use without revision
61 – 80	Feasible	Feasible for use with minor revisions
41 – 60	Fairly Feasible	Several revisions are required before use
21 – 40	Less Feasible	Not Feasible for use
0 – 20	Not Feasible	Should not be used

2. Practicality Analysis Technique

Practicality analysis was conducted to determine the responses of educators and students toward the *AstroMotion* media. Teachers and students were asked to provide objective assessments of various aspects by selecting one of four statements: strongly agree, agree, disagree, and strongly disagree. The evaluation was carried out by checking the appropriate score on the questionnaire sheet.

The formula used to calculate the average score of teacher and student responses to the media is as follows[28]:

$$R = \frac{\sum x}{\sum xi} \times 100\%$$

Description::
R : Response
∑x : Total Score
∑xi : Maximum Score

To strengthen the response data from teachers and students, the standard average analysis table below was used.

Table 2. Guidelines for Teacher and Student Response Questionnaire Scores [29]

Score Range (%)	Assessment Category	Description
81 – 100	Very Practical	Feasible for use without revision
61 – 80	Practical	Feasible for use with minor revisions
41 – 60	Fairly Practical	Revisions needed before use
21 – 40	Less Practical	Not feasible for use
0 – 20	Not Practical	Should not be used

3. Effectiveness Analysis Technique

Effectiveness analysis was conducted based on the results of the pre-test and post-test administered to the students. The purpose of this analysis was to determine the extent to which *AstroMotion* media was effective in improving students' understanding of Natural Science subjects, particularly on the topic of the solar system.

The improvement in understanding can be measured using the calculation of pre-test and post-test scores by applying the N-gain formula, as follows:

$$N - gain = \frac{Posttest\ Score\ -\ Pretest\ Score}{Maximum\ Score\ -\ Pre-test\ Score}$$

Description:
Post-test Score : The score obtained by students after the learning process
Pre-test Score : The score obtained by students before the learning process
Maximum Score : The highest possible score

The calculated N-gain (g) results are then categorized into criteria based on the following table:

Table 3. N-gain Criteria [30]

N-gain	Criteria
g > 0.7	High
0.3 ≤ g ≤ 0.7	Medium
g < 0.3	Low

RESULTS AND DISCUSSION

This development research produced a product in the form of *AstroMotion* learning media, which was developed using the ADDIE development model. The ADDIE model consists of several phases as previously described. The following is a further explanation of the results of the development that has been carried out:

1. **Analysis Stage**

In education, the analysis stage was conducted to identify learning needs, analyze student characteristics, and determine learning objectives[31].

The data collection takes place at MIS Al-Barkah through observation and interviews with the sixth-grade teacher, which indicate that the teaching process remains traditional, relying on lectures and textbooks without the use of visual tools. This results in low student learning outcomes, particularly in understanding abstract concepts such as planetary rotation and differences in the characteristics of celestial bodies. This situation highlights the relevance of interactive visual media. Media such as *AstroMotion* can become an innovative solution because it promotes hands-on and experiential learning as well as the visualization of celestial motion, which aligns with the cognitive development stage of elementary school students.

The identification results show that students are in the concrete operational stage, in which they learn concepts more easily through concrete and visual materials[32]. Therefore, abstract learning tools such as textbooks or verbal explanations alone are considered less optimal. By demonstrating non-digital simulations such as *AstroMotion*, students can observe planetary movements dynamically, thereby stimulating active participation and developing critical thinking skills.

The contribution of this study is the development of motion-based simulation media resources, which have not been widely used in the context of science instruction in elementary schools, particularly in the field of solar system studies. Well-designed instructional media greatly support students in processing and understanding learning materials[33]. These results reinforce the finding that visual and interactive media are very effective in building conceptual understanding and promoting active student engagement.

2. **Design Stage**

The design stage of the ADDIE model is the second and most crucial phase in the instructional design process. The purpose of this stage is to design the learning process in detail. This stage includes curriculum development, the selection of teaching methods and instructional tools, as well as the development of assessment plans. The design stage requires creativity and critical thinking to ensure that all instructional elements are integrated and effective in achieving the objectives established in the analysis stage[34].

The results of the design stage show that the researcher arranged the material sequentially according to the complexity of the topic, selected a realistic and informative 3D solar system model, and integrated simple technology, such as a mini DC motor, to simulate planetary rotation. This media emphasizes not only aesthetics and appeal but also content accuracy and the meaningfulness of learning tasks. In addition, the researcher also developed student worksheets and user guides for the media resources, as well as designed assessment tools in the form of pre-test and post-test questions to evaluate the effectiveness of the media resources.

Through this discussion, it is revealed that the media was developed by considering the characteristics of students in the concrete operational stage, thereby prioritizing the use of visual and motor elements that assist students in understanding abstract phenomena in practice. The addition of motorized planetary motion simulations is also intended to enhance students' cognitive and emotional engagement in the learning process, which is consistent with the constructivist approach to learning natural science[35].

The advantage of *AstroMotion* media, which combines visual, mechanical, and structured assessment elements, is its ability to provide a comprehensive learning experience. Instructional media in the field of education play a highly important role and, therefore, must be aligned with the development of the times, learning objectives, and student characteristics[36]. Overall, *AstroMotion* media proves that the use of learning tools designed with consideration of students' needs can have a significant impact on improving learning outcomes.

The contribution of the design phase in this study is the integration of content, media resources, tasks, and assessment elements, which are organized comprehensively to create a coherent and engaging learning experience. This media provides a framework that can be replicated or further developed in other Natural Science learning contexts and serves as an inspiration for teachers and media resource developers to create similar media that foster students' critical thinking. The results not only enrich Natural Science instructional practices but also have the potential to contribute to more contextual and engaging learning in elementary schools.

3. **Development Stage**

At this stage, what is highly important is the instructional designer's ability to select and

determine appropriate methods, media, and learning strategies to deliver the content or material of the learning program[37].

The process of constructing the *AstroMotion* media device began with the collection of materials and the assembly of its main components. The base of the media device was made of plywood, approximately 120 cm in size, serving as the support for the entire solar system. The planets were made from proportionally sized polystyrene foam balls, painted according to their characteristics. The planetary orbits were arranged using flexible wire, forming circular paths around the Sun at the center. The main drive of the media device was a mini DC motor connected to AA batteries and controlled by a small switch. This motor was used to rotate the planets automatically.

After the development phase was completed, the researcher proceeded with product validation involving media and content experts. The purpose of this validation was to obtain feedback from the validators to assess the validity of the *AstroMotion* media. The opinions and suggestions from the experts served as the basis for the researcher to make improvements or modifications to the developed media.

The validation results from media and content experts are as follows:

Table 4. Recapitulation of Validator Results

Validator	Score (%)	Criteria
Media Expert	89.4	Very Feasible
Content Expert	90.0	Very Feasible

Based on the recapitulation results presented in the table above, the media expert obtained a score of 89.4%, while the content expert obtained a score of 90%. This indicates that the *AstroMotion* media is very feasible to use without revision and is appropriate for use in the Natural Science learning process on the topic of the solar system.

Nevertheless, there was a suggestion from the validator regarding the improvement of the appearance of the *AstroMotion* media. Based on this suggestion, the researcher made revisions to enhance the quality of the developed instructional media. The following is a comparison of the *AstroMotion* media before and after the revision:

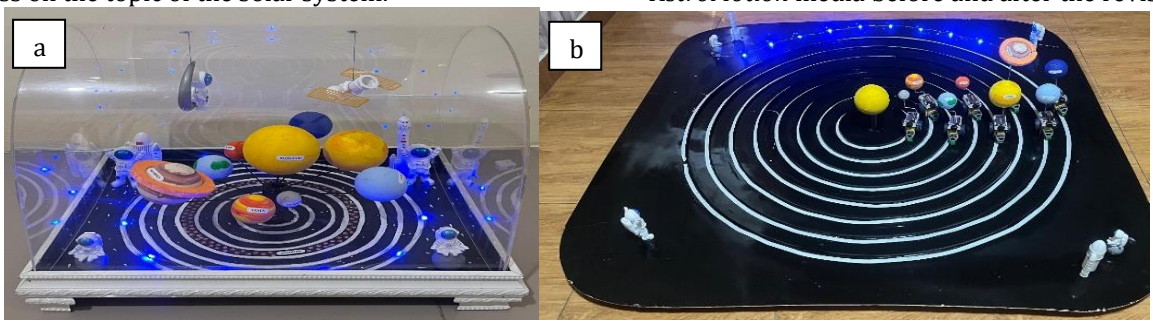

Figure 2. (a) *AstroMotion* Media Before Revision (b) *AstroMotion* Media After Revision

This media was developed as a solution to the limitations of traditional learning methods, which tend to be passive and lack active student involvement, particularly in understanding abstract concepts such as planetary motion in the solar system. Instructional media function as supporting tools in the teaching and learning process. Any form of tool or resource that can be used to stimulate thinking, emotions, attention, as well as learning abilities and skills, can contribute to the creation of an effective learning process [38]. These results indicate that the media have fulfilled the feasibility aspects in terms of content, presentation, visual appearance, and ease of use.

4. Implementation Stage

At this stage, the developed media was implemented in a real situation, namely in the classroom [39]. The purpose of this implementation activity was to determine the practicality and effectiveness of the developed media. The level of practicality of the *AstroMotion* media was identified based on the results of questionnaires administered to students and teachers after using the media in the learning process. The practicality results of the media are presented in the following table:

Table 5. Recapitulation of Media Practicality Results

Respondent	Score (%)	Criteria
Teacher	90.00	Very Practical
Students	88.43	Very Practical

Based on the recapitulation results of media practicality presented in the table above, the teacher obtained a score of 90%, while the students received a score of 88.43%. This indicates that the *AstroMotion* media falls into the category of very practical and can be used effectively as a learning tool in Natural Science, particularly in the topic of the solar system. The effectiveness of using *AstroMotion* media is observed through the pre-test and post-test scores. The results of the pre-test and post-test from the use of *AstroMotion* media in Natural Science learning are presented in the following table:

Table 6. Pre-test and Post-test Results

Test Type	Score	Gain	N-gain	Description
Pretest	57.7	30	0.71	High
Posttest	87.7			

Based on the data analysis results presented in the table above, the average pre-test score of students before using the *AstroMotion* media is 57.7. After the learning process is conducted using the *AstroMotion* media, the average post-test score increases to 87.7. Thus, there is a gain of 30 points between the pre-test and post-test results. This improvement is then analyzed using the N-gain formula, and the result is an N-gain score of 0.71, which is classified in the high category.

These results indicate that the *AstroMotion* media has a positive effect on student learning outcomes, particularly in enhancing critical thinking skills on the topic of the solar system. This significant improvement also reflects that visual and interactive instructional media can help students understand abstract concepts in a more concrete, engaging, and enjoyable manner.

Teachers are required to develop their skills in creating instructional media that are engaging, interactive, enjoyable, and applicable to teaching and learning activities[40]. This emphasizes the importance of implementing innovation in Natural Science learning at the elementary school level. Such innovation is not limited to the use of digital technology but also includes physical and manipulative instructional media that can bridge abstract scientific concepts with real-life experiences that students can directly perceive.

The proper and effective use of media will represent the successful delivery of the material taught by the teacher to the students[41]. During the learning process, students show high enthusiasm when interacting directly with the media. They can observe planetary movements, engage in group discussions, and respond to guiding questions from the provided worksheets. These activities encourage them to think critically, evaluate information, and draw conclusions based on direct observations.

5. Evaluation Stage

Evaluation is a process to determine whether the instructional system that has been developed aligns with the initial expectations or not[42]. Evaluation in this study is carried out in two forms: formative assessment and summative evaluation. Formative evaluation is conducted in stages during the development of the *AstroMotion* media, including key stages such as review by content and media experts, as well as trials with sixth-grade students at MIS Al-Barkah. The review by content experts aims to ensure the alignment of the educational content with the curriculum and learning objectives, particularly on the topic of the solar system. On the other hand, the review by media experts focuses on assessing visual aspects, clarity of presentation, interactivity, and the suitability of the media design with the characteristics of elementary school students.

After being modified based on input from the experts, the media was directly tested on students as the end users. At this stage, students were asked to complete a questionnaire to evaluate various aspects such as the attractiveness of the media, ease of use, clarity of content, as well as its contribution to understanding solar system concepts and developing critical thinking skills. The research results show that the majority of students gave positive responses to the *AstroMotion* media, both in terms of its design and its function in visualizing and explaining planetary motion interactively.

Meanwhile, after the media resources were fully developed and implemented in the learning process, a final evaluation was conducted. The purpose of this evaluation was to measure the effectiveness of the media resources in improving students' learning outcomes and critical thinking skills. Data were collected through pre-tests and post-tests, then analyzed to identify differences in learning outcomes before and after the use of the media resources. The analysis revealed a significant improvement in students' critical thinking skills, as evidenced by the increase in test scores and their ability to reason, analyze relationships among planets, and generalize various phenomena in the solar system.

The results of both formative and summative evaluations show that the *AstroMotion* media is very effective and feasible for use as instructional media in teaching the solar system, particularly in enhancing students' critical thinking skills. This is supported by research conducted by[43] which states that the use of media related to the solar system significantly improves students' critical thinking abilities. These evaluation results contribute significantly to the field of primary education, especially in the development of visual and interactive media. *AstroMotion* not only bridges the gap between abstract concepts and students' real-world learning, but also opens new possibilities for developing educational media using simple technology.

It is recommended that teachers use this media as an effective alternative instructional tool in Natural Science learning, particularly in the field of solar system studies. This study also opens up possibilities for further development, such as integrating the media with augmented reality (AR) or automated motion sensors, which would enable more modern and immersive instructional visualizations.

CONCLUSION

Based on the research findings and data analysis, the *AstroMotion* media developed through the ADDIE model is declared feasible, practical, and effective for use in Natural Science learning on the topic of the solar system. The feasibility aspect is evidenced by the validation results from media experts with a score of 89.4% and from content experts with a score of 90%, both of which are categorized as very feasible. In terms of practicality, this media received very positive responses from students with a score of 88.43% and from the teacher with a score of 90%, indicating that the media is easy to use and engaging. Meanwhile, the effectiveness of the media is shown through its implementation in the sixth-grade class at MIS Al-Barkah, which showed a significant improvement in student learning outcomes, with an average N-gain of 0.71, categorized as high. Thus, the *AstroMotion* media can serve as an innovative alternative in Natural Science learning to help achieve learning objectives optimally while also developing students' critical thinking skills, enjoyably and contextually.

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