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The Effectiveness of Steam-Based Interactive Module to Improving Learning Outcomes of Elementary School Students

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Abstract: This study aimed to determine the effectiveness of STEAM-based interactive modules in improving students' critical thinking skills. This research is motivated during the learning process in the classroom; students tend to be passive; their curiosity is very low and their enthusiasm in the learning process is very low; this has an impact on low student learning outcomes. This research is a Research and Development (R&D) using the Borg and Gall model. Data collection techniques with interviews, questionnaires and tests. The data analysis technique in this study used descriptive analysis techniques by analyzing validation data by expert validators and practitioners. The results showed that the results of the assessment of the three validators showed good results; the assessment of the validators was also converted into the feasibility of a module, including validator 1 with a score of 90 in the "Very Good" category, validator 2 with a score of 75 in the "Good" category and validator 3 scores 84 with the category "Very Good" and the results of the effectiveness test on the module also get a significant value. The average pretest score in the experimental group was 62.75, and the posttest was 80.8, while in the control group, the average pretest score was 61.15, and the posttest score was 80.8. From these results, it is known that there is an increase in student learning outcomes, so the STEAM-based interactive module is effectively used for fourth-grade elementary school students.

Keywords: Interactive module, STEAM, critical thinking

1. Introduction

Education is an effort made consciously by those who initially cannot become able, from those who do not know to know, which is formed through guidance, teaching and training for students to prepare students who face their roles in the future (Yoon et al., 2014). By conscious effort, it is meant that education is carried out and implemented based on plans and processes that are mature, steady, clear, complete, and comprehensive based on rational-objective thinking (Widodo, 2019). The goal is to form students with character so that students can think critically and contribute in the future.

In the 21st century, there is an assumption that individuals live in an environment full of technology with much information. The acceleration of technological progress is very high, so new collaborations are created (Mihladiz & Duran, 2014). Rapid technological developments occur in various countries and even almost all countries in the world and the existence of world competition both in the economic, political, socio-cultural and also in the field of education (Hidayat et al., 2021). In education, it is very encouraging for an educator or teacher to create more innovative and creative things in learning materials; the goal is to help students think critically to face challenges in the future and become a provision for students to compete. Amran et al. (2019) states, students living in the 21st century must master science, metacognitive skills, be able to think critically and creatively and communicate or collaborate effectively; this situation illustrates the gap between expectations and expectations. Schellinger et al. (2017) states that the fast development of science and technology cannot be avoided but must be faced and mastered. In facing the era of globalization, mastery of science and technology is a must, it requires various parties to develop their abilities related to technological developments.

Based on the teacher's statement at Gondosari Elementary School, Gebog District, Kudus Regency, through interviews with class teachers that were conducted on Tuesday, 10 May 2022, researchers obtained data that during the learning process in class, students tended to be passive, their curiosity was very low and enthusiastic in the learning process very low. With limited facilities and infrastructure in the classroom, teachers need more knowledge and minimal references, so in learning, teachers only use 2013 curriculum textbooks and also only use learning media around the school. This causes students to be very passive in learning; besides that, their enthusiasm for learning decreases; they do

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not want to think critically and only rely on explanations from the teacher (Sugiyono, 2021). In addition, students are less interested in innovating, creating and collaborating with their abilities, so learning is very passive in class; there needs to be feedback between teachers and students or students with other students (Al-Zahrani, 2015). In addition, student learning outcomes are very low, less than the predetermined criteria limits.

Based on the reality in the field, in this study, researchers are interested in conducting research and developing STEAM-based interactive modules for elementary schools. This STEAM-based interactive module can help facilitate the learning process and is expected to equip students to be able to improve their ability to think critically. Thus, researchers are interested in conducting research with the title "Development of STEAM-Based Interactive Modules for Grade IV Elementary School students". This study aimed to determine the effectiveness of STEAM-based interactive modules in improving students' critical thinking skills. This research is motivated during the learning process in the classroom; students tend to be passive, their curiosity is very low and their enthusiasm in the learning process is very low; this impacts low student learning outcomes.

2. Literature Review

According to Tan et al. (2017) students want to compete in the globalisation era, they must be able to communicate, collaborate, think critically, and be creative. One of these aspects is STEAM learning, where learning creates collaboration and requires students to think critically, interact and make children more creative. STEAM stands for Science, Technology, Engineering, Art, and Mathematics. It is a learning approach that expands knowledge, science, and humanities for students to develop skills in the 21st century (Wahyuningsih et al., 2020). Ridwan et al. (2022) stated that STEAM empowers teachers to present learning that fosters creativity, collaboration and critical thinking with project-based and problem-based learning. STEAM, as the integration of art disciplines into the curriculum and learning in science, technology, engineering and mathematics, becomes an integrated approach that can be implemented in the learning process, especially in elementary schools (Zayyinah et al., 2022).

According to Holbrook et al. (2020) there are important points in the STEAM approach, including 1) STEM learning does not conflict with STEAM learning but enriches and expands its scope, 2) STEAM learning is a curriculum philosophy that empowers science teachers in developing a humanistic vision of education in the 21st century, 3) STEAM learning also provides creative design space for teachers in various learning fields to collaborate in developing an integrated curriculum, 4) educators who apply the STEAM approach to learning can take inspiration from project-based learning.

Badriyah et al. (2020) argues that there are several steps in the STEAM approach to planning the learning process and facilitating the learning process as follows: 1) focus: in this step, we choose a question or problem that is important to answer or find a solution for. It is important to focus on how this question or issue relates to the chosen area of content and art; 2) details: in this detailed step, look for the dominant element relevant to the problem or question. When we observe the relationship with other fields or why the problem occurs, then we begin to dig up a lot of information about the background of the problem; that's when the process skills that students have to answer these questions are needed, 3) discovery: in this step, students research existing solutions, as well as what has not been implemented/not working based on existing solutions. As a teacher, we can use this stage to analyze the gaps that students may have in a particular skill or process, 4) application: it is at this application stage that learning will be more interesting. After students are involved in a formulation and answer all problems and questions, then students analyze the solution to overcome these problems. This is where they use the knowledge and skills taught and apply it in the discovery stage; 5) presentation: after students find solutions and alternatives, the next step is to share them with other students, or what is commonly called presenting. This stage is important because the work of students is presented/published to obtain feedback as a way to express based on the perspective of the students themselves related to the questions or problems faced and 6) link: in this last stage, students have the opportunity to reflect on the feedback that has been shared to see their processes and skills. Based on this reflection, students can revise their work according to their needs and produce better solutions.

Perignat & Katz-Buonincontro (2019) argue that STEAM learning can develop students' creativity and critical thinking skills to improve problem-solving skills in the real world. Critical thinking is a directed and clear process used in developing mental activities such as solving problems, making decisions, analyzing opinions and conducting scientific research. Critical thinking skills are individual skills in using their thinking processes to analyze arguments and provide interpretations based on perceptions through logical reasoning, analysis of assumptions and logical interpretations (Syukri et al., 2022).

Wilson et al. (2021) explains that critical thinking ability is a person's ability to use logic; logic is a person's way of thinking to gain knowledge accompanied by an effective assessment of the truth based on certain patterns of reasoning. Rahmawati et al. (2019) states that critical thinking skills are skills to identify and determine a problem, which includes determining the essence, looking for similarities and differences, digging up relevant data, considering and assessing, which includes distinguishing between facts and opinions, determining assumptions, separate prejudices and social influences, weigh consistency in thinking, draw conclusions that can be accounted for by relevant data and estimate the consequences that will arise. Wijaya also argues that there are characteristics in critical thinking, namely: a) good at detecting problems, b) able to distinguish relevant from irrelevant ideas, c) able to identify differences or information

gaps, d) can distinguish between logical and illogical opinions, e) able to test assumptions carefully, and f) able to draw generalization conclusions from the data that is already available with data obtained from the field.

A teacher can design the learning process by choosing strategies, approaches, and methods that are by the characteristics of the subject, according to the characteristics of the students and also paying attention to the infrastructure owned by the school so that it can support the learning process by the students' environment and the learning process can take place effectively and efficiently. Arora et al. (2018) argues that the learning planning process is a development process from the applicable curriculum, which is then used as a learning program and then as a guide by the teacher in carrying out the learning process. Therefore, an educator must have many references when carrying out the learning process, such as guidebooks, modules, digital books or other references that can support the learning process so that students can receive the subject matter well.

3. Methodology

This research is a research and development (R&D). The research and development procedure that the researcher uses used the Borg & Gall (2002) model, which consists of 7 (seven) stages. The population frame of the research was twenty-nine fourth-grade students from Gondosari 1 and Gondosari 4 Elementary School, Indonesia. This research is a Research and Development using the Borg and Gall model. Data collection techniques with interviews, questionnaires and tests. The data analysis technique in this study used descriptive analysis techniques by analyzing validation data by expert validators and practitioners.

This research is a research and development (R&D). Data collection techniques used in this study were interviews, questionnaires, and tests. This study uses the Borg and Gall model to develop STEAM-based interactive modules to improve students' critical thinking skills (Aka, 2019). In the research and development procedure, the researcher uses the Borg & Gall model, which consists of 7 (seven) stages including: 1) Potential and problems: the findings in the field of teachers are only guided by thematic books and the lack of variety of learning media so that students only rely on information from a teacher. This impacts student activity, which could be much higher in the learning process. The researcher also analysed the problems faced in the low mastery of concepts and critical thinking skills of fourth grade students. The analysis carried out includes a needs analysis to determine the need for a learning module that can provide a real learning experience in improving students' critical thinking skills, 2) Data collection: researchers collect data that is used as material for developing modules and overcoming potential problems. The instruments used in data collection are interview sheets, questionnaires and tests, 3) Product design: in this stage, researchers develop learning media in STEAM-based interactive modules with specified specifications. Researchers developed products; researchers developed STEAM-based interactive modules for fourth-grade elementary school students in Gebog District: a) the design of STEAM-based interactive modules for students' critical thinking skills is made based on potential and problems, b) the delivery of thematic material is adjusted to the material for class IV theme 1 The Beauty of Togetherness, c) the product in this research is an interactive module based on STEAM in learning theme 1 The beauty of togetherness that can be used by students to study independently, d) the book section contains a cover page, preface, table of contents, Guide to module usage, core competencies & basic competencies, learning materials, bibliography, 4) Design validation: design validation is an activity process to assess whether the STEAM-based interactive module for the critical thinking ability of fourth-grade elementary school students is valid or not. Design validation is done through expert judgment by experts. Each expert was asked for advice and input, so that further the weaknesses of the developed product could be identified. These strengths and weaknesses will be input and reference in developing and improving the validator's learning module; 5) Design revision: design revisions are carried out after being validated by experts, and then the module is repaired. After the revision, the product developed as an interactive STEAM-based module is ready to be tested at the next stage, 6) Initial trial: in this case the researcher tested the product on the research subject. In this step, experiments are carried out as data collection on the developed learning module. This field trial is intended to determine the effectiveness of the module product. Students can achieve the product's effectiveness according to the learning objectives, and the post-test results of the experimental group are better than the control group, 7) Product revision: product revisions are carried out after product trials are carried out. Product revisions are carried out to improve the module products developed. After the revision, the final product of the STEAM-based interactive module for grade IV elementary school was obtained that could be used in learning.

3.1 STEAM-Based Interactive Module Feasibility Analysis

The validity test is carried out to assess the feasibility of a product being developed. The steps of data analysis techniques to determine the feasibility of a module are as follows: the assessment sheet consists of 4 alternative answers, namely 1,2,3 and 4. Determine the module eligibility score using the assessment criteria provisions in Table 1.

Table 1. Score scoring guidelines

Score	Eligibility answer choices
4	Very good
3	Good

2	Moderate
1	Poor

The maximum score is 4 (four), and the minimum score is 1 (one). Calculate the average score of each data that has been collected. The formula calculates the average score:

$$P = \frac{x}{xi}\ x\ 100\% \qquad (1)$$

The formula used for the overall data processing:

$$P = \frac{\sum x}{\sum xi}\ x\ 100 \qquad (2)$$

Description:
p = percentage
Xi = the ideal number of scores in one item
$\sum$x = total number of respondents' answer scores
$\sum$xi = total number of ideal scores

The results obtained from the average calculation score of each validator are then converted to statements to determine the criteria for the product being developed. The product validity score conversion show in Table 2.

Table 2. Product validity criteria

Score	Criteria	Media criteria
86 – 100	A	So worth it
71 – 85.99	B	Worthy
56 – 70.99	C	Quite decent
< 56	D	Not worth it

3.2 STEAM-Based Interactive Module Effectiveness Data Analysis

After obtaining pretest data from the control and experimental groups, initial data was analysed. The aim is to determine whether the two classes used in the trial are in the same initial conditions. The analysis includes the normality and similarity tests of two variances (homogeneity test).

3.2.1 Normality Test

According to Kwak & Park (2019), the normality test aims to determine whether the two groups' test results data are normally distributed. Thus, the hypothesis for the normality test is as follows:
Ho: test results data for the experimental class and control class are normally distributed
Ha: test result data for the experimental class and control class are not normally distributed

Test the normality of the test results using the Shapiro-Wilk test assisted by SPSS. The normality test results can be seen in the printout of the analysis results of the Asymp column. Sig. (2-tailed). If the value obtained > 0.05 then Ho is accepted.

3.2.2 Homogeneity Test

According to Chebana & Ouarda (2007), the homogeneity test aims to determine whether the control class and the experimental class have the same level of variance or not. The hypothesis for the homogeneity test is as follows: Ho: the variance of the control and experimental classes is the same.

The similarity test of the two variances used Levene's test with the help of SPSS. The homogeneity test results can be seen in Sig's printout of the analysis results. A column with Levene Statistics, if the results obtained > 0.05 then Ho is accepted.

3.2.3 Hypothesis Testing or t-test

Learning effectiveness is obtained through data analysis of improving student learning outcomes. The experimental data analyzed were pre-test and post-test data. The pre-test and post-test data from the control group and the experimental group were analyzed using the N-Gain or n-gain formula:

$$N - gain < g > = \frac{Posttest\ score - Pretest\ score}{maximum\ score - Pretest\ score} \quad (3)$$

The increase in student learning outcomes calculated by the n-gain formula can be divided into the following categories. Whether there is a difference in learning outcomes in the control and experimental groups is indicated by the Sig value. (2 tails). If the value of Sig. (2-tailed)> = 0.05 then H0 is accepted. On the other hand, if Sig. (2-tailed) < = 0.05 then H1 is accepted. The t-test criteria in the pretest data analysis are the value of Sig. (2-tailed)> = 0.05. In the posttest data analysis the criteria is the value of Sig. (2-tailed) < = 0.05. Thus, the STEAM-Based Interactive Module effectively improves students' critical thinking skills, increasing their learning outcomes.

Table 3. N-gain interpretation criteria

Score N-gain	Interpretation criteria
g> 0,7	High
0.3 < $g \leq$ 0.7	Moderate
$g \leq$ 0.3	Low

4. Results

This research was conducted at Elementary School No. 1 Gondosari as the experimental group and Elementary School No. 4 Gondosari as the control group. The result of this research is to produce a STEAM-based Interactive Module. This Interactive Module will be developed using an approach so that the tasks given are based on the approach used, namely the STEAM (Science, Technology, Engineering, Arts, and Mathematics) approach in each learning activity. This Interactive Module can be accessed via a computer or laptop. This study aims to determine the effectiveness of the developed product. The results obtained based on the research on the development of interactive modules that have been carried out are as follows.

4.1 Potential and Problems

In the first stage, before carrying out the product development process, the researcher must conduct a field study to identify the potential problems that exist in the field so that it can be used as a reference in developing the product. The search for potentials and problems was conducted by observing and interviewing teachers and students in grade IV Elementary School in the Gebog district. The results obtained are that in learning, the teacher still needs to use technology as a learning tool, so in learning, the teacher only uses the teacher's manual, which causes students to be less interested in the learning process and to feel bored quickly.

4.2 Data Collection

At this stage the researcher collects various information that can be used as material for designing products, hoping that these products can overcome the problems in the field. The data collected is obtained from the results of the needs analysis that has been carried out.

4.3 Product Design

Before designing a product, planning is done first. This planning process is carried out to structure and plan the development process. This planning includes analysing core and basic competencies, analyzing learning materials, choosing letters, using images and videos, choosing colours, and STEAM-based module components. STEAM-based interactive module planning is also designed according to the student's character so that it is easy to learn by students both individually and in groups.

4.4 Product Validation

After the product has been designed, the next step is product validation by material or media experts. Furthermore, the validation results are calculated and analyzed to determine the feasibility of the learning media. The data can be presented as a diagram for more details.

Based on Fig. 1, the results of validation 1 obtained a score of 90 and then converted into product eligibility criteria, which can be categorized in the "Very Eligible" criteria. For acquiring a score in validation 2, obtaining a score of 75 and then converting it, the STEAM-based interactive module can be categorized in the "Eligible" criteria. In validation 3, it obtained a score of 84 and then converted into a reference product eligibility criteria, which can be categorized in the "Eligible" criteria. In addition, the results of teacher and student responses after using the interactive module showed a very good response. The teacher's response showed a result of 87.5 with a very decent category, and the student responded 88% with a very decent category. From these results, teachers and students are very enthusiastic. They can accept interactive modules as learning media that students can learn individually or in groups to increase student activity, collaboration, communication and innovation in the technological era.

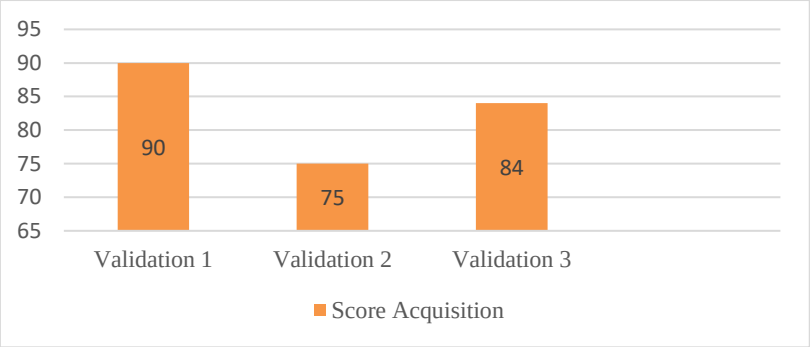

Figure 1. STEAM-based interactive module validation score acquisition

Based on the explanation above, the researcher can conclude that the STEAM-based interactive module product is suitable for the learning process in class IV, especially on theme 1, the Beauty of Togetherness, the sub-theme of My Cultural Diversity. Students will be directly involved, and using these media increases the enthusiasm and motivation of students to participate in learning.

4.5 Product Revision

Product revisions are carried out after the validator has assessed the product. Revision of the module is not done in total, but only implements suggestions and comments from some validators. Suggestions from validators include: 1) on the home menu, the arrows are adjusted and shifted to the right, 2) the writing of references is adjusted to the guidelines for writing a bibliography, and 3) writing references is synchronized with the table of contents and replaced with a bibliography.

From some suggestions and comments given to the validator, the researcher then revises the module so that the developed module is better and suitable for students to use in the learning process. Here are the sections that need to be revised based on suggestions from the validator on the STEAM-based interactive module.

Figure 2. STEAM-based interactive module before revision

On the home menu button and arrows, revisions are made based on suggestions from the validator, namely by changing the position on the right. Then, the reference writing must be replaced with a bibliography, which is also adjusted to the systematics of writing a bibliography.

Figure 3. STEAM-based interactive module after revision

By revising the appearance of the STEAM-based interactive module, the interactive module is clearer and more interesting for both teachers and students in the learning process. For the other part, the interactive module is already good and feasible, so there is no need to revise it again.

4.6 Product Trial

The product was tested at Elementary School No. 1 Gondosari, as an experimental group. Test data on the effectiveness of STEAM-based interactive modules were obtained by giving evaluation questions to students at the end of the lesson. Based on Fig. 4, the data on the effectiveness of STEAM-based interactive modules in improving student learning outcomes experienced significant differences. Fig. 4 shows that the average value of the experimental group is greater than that of the control group. The average value of the experimental group was 80.8, with the highest score of 95 and the lowest score of 70, while the control group achieved an average score of 75.70, with the highest score of 90 and the lowest score of 60. The effectiveness test in the experimental group obtained an N-gain of 0.48 in the medium category. In comparing the values in the experimental group and the control group, the value of t count > t table is 2.161 > 1.683, so this STEAM-based interactive module media is effective for use in learning in grade IV elementary school.

Based on the average score obtained by students, it shows that using STEAM-based interactive modules effectively improves students' critical thinking skills so that student learning outcomes increase in learning theme 1 The Beauty of Togetherness Subtheme of My Cultural Diversity in Grade IV Elementary School.

5. Discussion

Based on Fig. 4, the data on the effectiveness of STEAM-based interactive modules in improving student learning outcomes experienced significant differences. The diagram shows that the average value of the experimental group is greater than that of the control group. The average value of the experimental group was 80.8, with the highest score of 95 and the lowest score of 70, while the control group achieved an average score of 75.70, with the highest score of 90 and the lowest score of 60. From the effectiveness test in the experimental group, an N-gain of 0.48 in the medium category was obtained. In comparing values in the experimental group and the control group, the value of t count > t table is 2.161 > 1.683, so this STEAM-based interactive module media is effective for use in learning in grade IV elementary school.

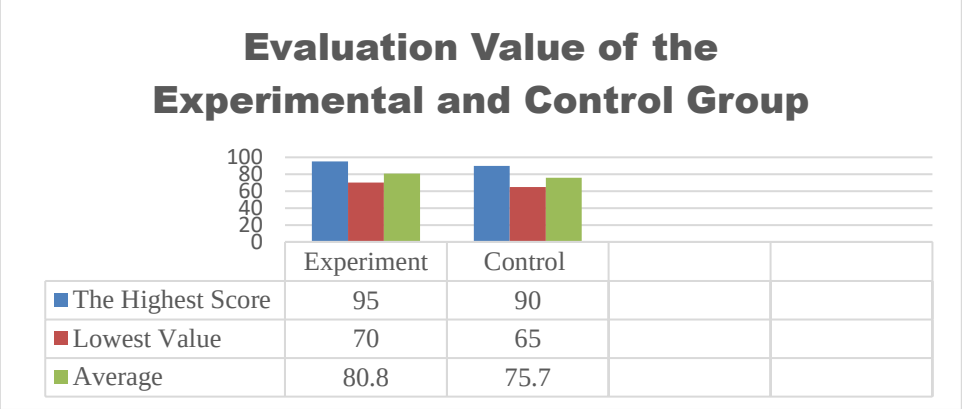

Figure 4. Evaluation value of the experimental group and the control group

According to Uğraş (2018), the STEAM education approach teaches individuals to build a mesh network from transdisciplinary knowledge, behavior, belief, skills, and action, as well as to prepare their problem-solving talents for real life. When learning through the system devised by this graduate institute, students were classified according to their learning styles, with visual type students outperforming verbal type students. There were no significant variations in learning effectiveness between sequential and global type students using the designed method. Teaching and learning It is expected that learning will frequently be carried out by assigning adequate time so that learning objectives can be successfully completed. It is possible to develop technology media and projects that are now being carried out. Furthermore, it allows students to be creative without relying on teachers' rules. Furthermore, it can demonstrate that STEAM improves not only cognitive but also affective skills.

6. Conclusion

Based on the results of the research that has been done, the average effectiveness test for the experimental group is 80.8 and the control group is 75.76. in the experimental group, an N-gain of 0.48 was obtained in the medium category. In the comparison of values in the experimental group and the control group, the value of t count > t table is 2.161 > 1.683, so this STEAM-based interactive module media is effective for use in learning in grade IV elementary school.

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