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Development and Effectiveness of STEAM-C Integrated Learning Devices to Improve Students' Creative Thinking Skills in Specific Cultural Context

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Abstract: Good learning devices greatly assist teachers in conveying the process of seeking knowledge to students. This study aimed to develop a STEAM-C (Science, Technology, Engineering, Art, Mathematics and Culture) integrated learning device in Masjid Kuno Taman, Indonesia to improve students' creative thinking skills. The learning devices included lesson plans, modules, and student worksheets. This research and development (R&D) used the ADDIE development model (Analysis, Design, Development, Implementation, and Evaluation). Subjects (n = 84) were selected by the cluster sampling method. The data collection techniques were focus group discussions (FGD), observations, tests,and questionnaires. The trial of using the product was carried out on mathematics teachers and students at SMP 10 Madiun and SMP 12 Madiun for the academic year 2021/2022, with a total of three teachers and 84 students. The results showed that the degree of validity of the learning devices was in the good category, as was the level of practicality seen in the presentation, use, time and readability. Furthermore, as seen from the four indicators, the devices developed effectively improve students' creative thinking skills, namely fluency in the high category and flexibility, elaboration, and originality in the medium category. As a result, the STEAM-C integrated learning device is recommended for use in mathematics learning to help students improve their creative thinking skills. Implications have been drawn, based on this research and other recent research in this area, for specific 'learning designs' in specific social contexts.

Keywords: STEAM-C, learning device, creative thinking ability.

Introduction

As a developing country, Indonesia is still dealing with problems in education, particularly learning achievement. The PISA (Programme for International Student Assessment) test results show one of the international scale indicators of accomplishment of Indonesian students. Indonesia has finished last in the last three competitions. In 2018, Indonesian students ranked 72nd out of the 78 participating countries (Schleicher, 2019). The low PISA results indicate that students have not yet mastered mathematical problem-solving abilities or skills. Students' creative thinking skills are still weak or low, indicating that they have not mastered problem-solving skills in mathematics (Munafiah et al., 2019). According to the 2015 Global Creativity Index survey results, Indonesia ranked 115th out of 139 countries. Indonesia has a Global Creativity Index score of 0.202. This score is still far below the country with the highest Global Creativity Index score of 0.970 (Florida et al., 2015).

Along with the problem of achievement, the fading of the nation's culture is one of the realities that can be recognised in terms of its negative influence. The lack of the next generation's desire to learn and pass that on causes local culture to deteriorate (Khumairoh, 2022). Some people begin to believe that anything traditional is ancient and outdated due to this way of thinking, which causes their interest in traditional arts to decline and they start to forget about them. The younger generation could be exposed to their local culture through formal education programmes (Ranjabar, 2006).

Learning designs created specifically for students are one of the ways that the educational sector could attempt to address some of these problems. It is envisaged that learning design will develop and implant national cultural values and enhance 21st-century skills. STEAM is one way that can be done, and it typifies 21st-century skills (Science, Technology, Engineering, Arts, and Math). According to Yakman & Lee (2012) and Nurhikmayati (2019), STEAM is an educational approach that encompasses and interprets five academic fields (science, technology, engineering, arts, and mathematics) to teach students critical thinking skills that are essential in the twenty-first century. It is vital to overcome the degradation of national culture due to globalisation, and the STEAM approach can be combined with culture (Huo et al., 2020; Wu et al., 2022; Guan & Zhan, 2021; Bedewy et al., 2022; Bahri et al., 2017). By exploring cultural diversity, STEAM and Culture (STEAM-C) integration can be an alternative learning design for developing an understanding of scientific principles and creative thinking skills.

So far, culture-based learning has not always had a place in the school curriculum, including the learning process of various subjects (Fahrurrozi, 2015). Not surprisingly, the impact of formal education is that students or graduates cannot appreciate traditional forms of knowledge and wealth in their cultural community (Grant & Gomez, 2000). Culture and learning are two things that cannot be separated, because culture makes a major contribution to the learning process (Kuswana, 2013). The process of internalising a culture into learning is one of the strategies for developing students' thinking skills by using a contextual approach as a learning concept that links educational material with real-world situations, so that students are able to make connections between the knowledge they have and its application in life. This strategy can provide the nurturant effect of developing skills such as critical logical thinking (Wisudawati & Sulistyowati, 2015).

Based on the research problem and its urgency, learning devices that integrate STEAM-C were developed in Masjid Kuno Taman to improve students' creative thinking skills. The learning devices developed were lesson plans, student worksheets and modules. In addition, learning tools were identified to assist teachers in conveying the process of knowledge acquisition to students (Purnamasari & Nur Wangid, 2016).

Literature Review

STEAM-C

STEAM and Culture Integration (STEAM-C) can be an alternative learning design to develop an understanding of scientific principles and creative thinking skills by exploring cultural diversity.

Learning methods and strategies can be flexibly used to adapt to the conditions of schools, students and the environment. Culture and STEAM are two answers to the implementation of mathematics education to answer future challenges (Abi, 2016). In STEAM, math plays an important role. As the parent of science, mathematics plays a vital role in the development of science, including STEAM (Suendarti, 2019). The study of culture-based mathematics is one approach that is expected to attract students to learn mathematics. Culture is something that is closely related to students. In essence, learning and culture are inseparable (Koentjaraningrat, 2007). Culture is a manifestation of learning that is implemented in everyday life.

This STEAM-C learning model uses Project Based Learning, which underlies the STEAM-C learning model. Project Based Learning (PjBL) is learning based on providing projects for students to work on. The project can be done in groups, with members of between four to five students, that have the skills needed to carry out the project, including planning, organising, negotiating and making agreements about the project being worked on (Mahanal, 2017).

The following are the steps for implementing learning using the PjBL-STEAM-C Learning Model (Krisdiana et al., 2022). Phase 1: Reflection (PjBL: Fundamental Questions), Phase 2: Research (PjBL: Designing Project Planning), Phase 3: Discovery (PjBL: Arranging Schedules), Phase 4: Application (PjBL: Project Completion Monitoring), Phase 5: Communication (PjBL: Testing Results and Evaluation).

Creative Thinking Ability

Creative thinking is a process that involves elements of originality, fluency, flexibility and elaboration (Susanto, 2013). Sani (2014) states that creative thinking is the ability to develop ideas that are unusual, of quality and appropriate to the task. Indicators of the ability to think creatively are, fluency, flexibility, originality and elaboration (Andiyana et al., 2018; Munandar, 2009).

Fluency is defined as the ability to create a myriad of ideas. The fluency aspect can be seen from students being able to respond with several alternative answers. Flexibility describes a person's ability to generate ideas of different categories or look at something (object, problem) from various points of view (Munandar, 2009). Students can analyse and solve a problem based on their creative ideas. Elaboration is the ability to propose various problem-solving approaches (Munandar, 2009). Elaboration is a bridge that must be crossed by someone to communicate their creative ideas to the public. Originality refers to the uniqueness of any given response. Originality is shown by a reply that is unusual, unique and rare. According to Filsaime (2008), original thinking is the ability to issue unique and unusual thoughts or ideas that are, for example, different from those in books or in the opinions of others. The development of the originality aspect is closely related to the fluency and flexibility aspects. Suppose fluency and flexibility are maximally developed in question-and-answer activities or discussions. In that case, the teacher would likely develop originality because originality will emerge if the teacher can develop fluency and flexibility.

Research Objectives and Questions

This research developed STEAM-C-based learning tools to improve students' creative thinking skills. The culture integrated into STEAM was the culture in the area where students lived, namely the Masjid Kuno Taman, and, specifically, a historical building located in the students’ environment. Its integration into STEAM involved the geometric shape of the building sections of the Masjid Kuno Taman. Students studied the history of the founding of Masjid Kuno Taman, analysed the elements of geometric shapes in buildings, then determined the area and volume and made a replica of the Masjid Kuno Taman based on the concept of spatial geometry. Culture in this study was a source of student learning, which included local wisdom values and historical buildings that, hopefully, made learning more meaningful. STEAM-C learning can be an alternative learning method for teachers to introduce culture to students and improve students' creative thinking abilities. This research could add to the literature regarding STEAM-C learning devices (lesson plans, modules, student worksheets) and could improve students' creative thinking abilities. The following are research questions to achieve the objectives of this study:

RQ1: What is the validity of STEAM-C-based learning tools that can improve students' creative thinking skills?

RQ2: What is the practicality of STEAM-C-based learning tools that can improve students' creative thinking skills?

RQ3: What is the effectiveness of STEAM-C-based learning tools that can improve students' creative thinking skills?

Research Framework

This study was structured according to the research framework illustrated in Figure 1. The fact that students have not mastered problem-solving skills in mathematics learning can be seen from the students' creative thinking skills, which were still weak or low (Munafiah et al., 2019). According to the 2015 Global Creativity Index survey, Indonesia was ranked 115th out of 139 countries and said to be low on the ability to think creatively (Florida et al., 2015). In addition, students, as the nation's next generation, lack interest in learning and inheriting local culture (Khumairoh, 2022). The current globalisation has greatly influenced the lives and mindsets of the younger generation to become more modern. This thinking has made some of them think that anything traditional is old-fashioned. Efforts to introduce local culture to the younger generation can be carried out through formal education channels (Ranjabar, 2006).

Efforts can be made in education through learning designs for students that can overcome the degradation of national culture due to globalisation, and the STEAM approach can be used in conjunction with culture (Huo et al., 2020; Wu et al., 2022; Guan & Zhan, 2021). STEAM and Culture Integration (STEAM-C) can be an alternative learning design to develop an understanding of scientific principles and creative thinking skills by exploring cultural diversity. STEAM-C learning tools must meet valid, practical and effective criteria to make these devices suitable for use in learning.

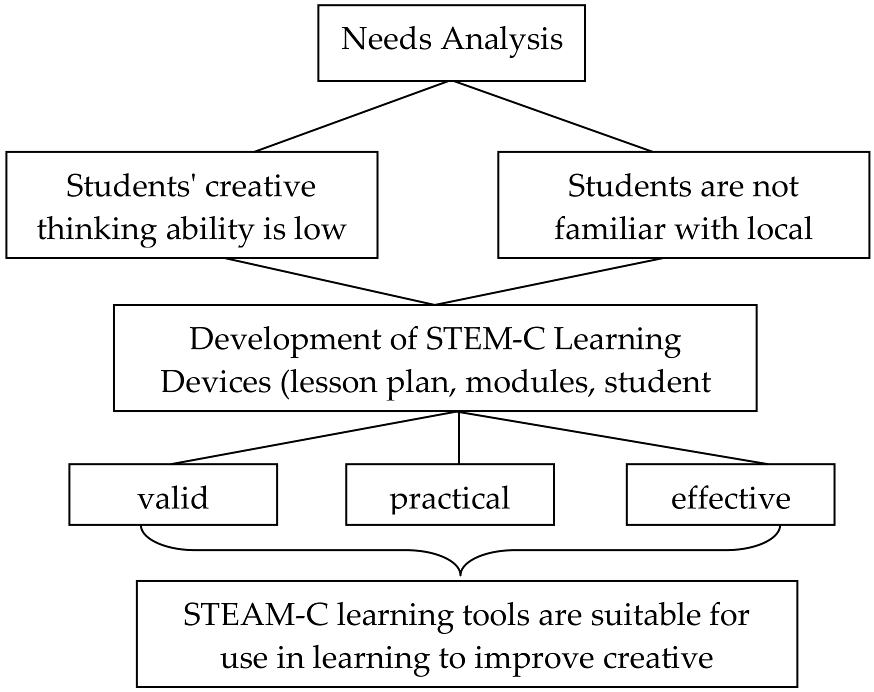

Figure 1: Research Framework

Methods

Research Design

This study aimed to develop a product and evaluate its validity, practicability and effectiveness in achieving its goals. This research was conducted from May to August 2022. This study is a Research and Development (R&D) scheme using the ADDIE (Analysis, Design, Development, Implementation, and Evaluation) development model (Branch, 2010). In the analysis stage, problem identification is carried out through a needs analysis. At the design stage, learning devices and product evaluation instruments are designed. At the development stage, learning tools are created and validated by experts. At the implementation stage, limited trials and field trials were carried out with students and teachers. At the evaluation stage, an analysis was carried out on the results of the learning device trials and the effectiveness of the learning devices developed. Lesson plans, modules and student worksheets were created as learning devices to be integrated with STEAM-C. The lesson plans employed the project-based learning model.

Population and Sample

The population in this study were grade VIII students at SMP 10 Madiun and SMP 12 Madiun, totaling 292 students. The sample in this study amounted to 84 students. The sample was obtained by the cluster sampling method. Cluster sampling is where the entire population is divided into clusters or groups. Furthermore, random samples are drawn from these clusters, all of which are used in the final sample (Wilson, 2014). The clusters in this study were classes at the school, which amounted to 10 classes, then three classes were randomly selected — one class for the limited trial of 10 students and two classes for the field trial of 74 students. In addition, three mathematics teachers were selected to assess the learning tools developed.

Instrument and Data Analysis

This study used FGD, observation, tests, and questionnaires as data collection techniques to obtain data in the form of facts and information regarding problems with the low ability exhibited by students creative thinking and test scores, and student and teacher responses to learning tools.

The test was intended to evaluate creative thinking skills such as fluency, flexibility, elaboration and originality (Treffinger et al., 2002; Munandar, 2009).

To see whether the learning device product was suitable for learning, the following three stages were carried out:

1) Validation data analysis, in which product validity was determined using a validation sheet evaluated by five validators consisting of two material experts and three learning device experts. According to Nieveen (1999), determining the validity of the developed product based on the correct theory and whether there is consistency between components, the validity of the product must be assessed by experts. The aspects assessed in the validation of learning devices were construct, material content and language (Retnawati, 2016). Validators validated the content of the material and the completeness of the components of the learning device developed. The validation results from the experts were used to improve the learning devices developed. The validity category followed the criteria from Arsyad in Rapi et al., 2021 as shown in Table 1:

Table 1: Validity Criteria

Score	Criteria
$3.5 \le V \le 4$	Very Valid
$2.5 \le V \le 3.5$	Valid
$1.5 \le V \le 2.5$	Quite Valid
$0 \le V \le 1.5$	Invalid

2) In the analysis of practicality data, the aspects assessed were presentation, usage, readability and time (Sukardi, 2008) to determine the practicality of learning devices obtained from student and teachers' response questionnaires. The total score of the assessment results by students and teachers is presented to determine the level of practicality, using the following formula (Trianto, 2011):

$$P = \frac{A}{B} \times 100\%$$

Description: P = percentage of student and teachers' response;
A = total score obtained; B = total ideal score

Learning tools meet the classic criteria of practicality if ≥ 70% of students give a positive response.

3) Data analysis for effectiveness were based on test results of students' creative thinking skills before and after participating in learning with the developed learning tools. Student test results were analysed using the normalised gain score (n-gain) (Hake, 1999) with the formula:

$$g = \frac{s_{post} - s_{pre}}{s_M - s_{pre}}$$

Description: g = n-gain score; ^{S}post = post-test score; ^{S}pre = pre-test score; ^{S}M = maximum score. Criteria for n-gain score: $g > 0.7$ (High); $0.3 < g < 0.7$ (Medium); $g < 0.3$ (Low) (Hake, 1999).

Results

A needs analysis was carried out for the learning devices that would be created once learning outcomes were examined. According to observations and interviews, the devices and learning processes used are still traditional and teacher-centered, impacting learning outcomes and students' creative thinking skills. Teachers have not encouraged students to work together to develop creative thinking skills. Due to time and capacity constraints, the STEAM-C approach was never implemented by teachers in SMP 10 Madiun and SMP 12 Madiun. In terms of students, in addition to low learning outcomes, cultural knowledge was still lacking. The low level of cultural knowledge can be seen from the results of interviews, which show that some students do not recognise the cultural history of the city of Madiun. Therefore, it is necessary to create learning devices integrated with STEAM-C to improve students' creative thinking skills, while also getting to know their culture, specifically that of Masjid Kuno Taman.

Activities carried out in the second and third stages, namely design and development, included compiling validation sheets, student questionnaire sheet, and test sheets. The lesson plans, modules and student worksheets were designed at this stage. The project-based learning model's syntax and the STEAM-C approach were used to create the lesson plans. The flat sides and light refraction were the learning materials. Reflection (preparing fundamental questions), research (designing project planning plans), discovery (scheduling), application (monitoring project completion), and communication (test results and experience evaluation) were the learning steps in the lesson plan (Krisdiana et al., 2022). The next task was to create the learning modules. The modules were designed to help students understand the material used to build the flat sides. Masjid Kuno Taman is the STEAM-C integrated module replete with culture. It was chosen due to the material and culture available in the Madiun Town area. The STEAM-C integrated learning device's initial design of teaching materials was in the form of a module, with the content consisting of the front cover, introduction, table of contents, study guide, concept map, a brief overview of Masjid Kuno Taman's culture, flat-side-space building material and light refraction material. The module included spatial drawings to help students visualise and comprehend the materials and images of Masjid Kuno Taman. In addition, there were sample questions and practice questions at the end of the chapter. There were two activities for students in the student worksheets: the first was making miniatures of Masjid Kuno Taman, and the second was making devices and observing the application of the concept of light refraction.

Validity of STEAM-C-based Learning Tools

Five experts validated the learning tools developed at this stage. Table 2 shows the average research tools. The validator assessment of each learning device yielded the following results: the lesson plan at 3.02, the module at 3.14 and the student worksheets at 2.98. They were in the good category based on these scores. In addition, the validator provided feedback and suggestions for improving learning tools. The validator's criticism and suggestions were then used to revise all learning devices to create learning tools worthy of being tested on a limited and a broad scale.

Table 2: The Experts' Validity Results of Learning Devices

Product	Expert					Average	Criteria
	1	2	3	4	5		
Lesson Plan	3.1	2.8	3.3	2.9	3	3.02	Good
Module	3.5	3	3.3	3	2.9	3.14	Good
Student Worksheets	3	2.9	3.1	2.9	3	2.98	Good

The learning device component is said to have valid criteria if it obtains a score between 2.5 - 3.5.

Practicality of STEAM-C-based Learning Tools

The fourth and fifth stages were implementation and evaluation. In the limited trial, the learning device was tested on 10 students. The teacher applied learning using the developed lesson plans, while students study the material using the developed modules and worksheets. Three math teachers evaluated the lesson plans' practicality. This product's practicality test considers presentation, readability, use and time (Sukardi, 2008). The data obtained was then analysed by determining the average for each component based on the assessment of the three mathematics teachers and 10 students. The questionnaire results on the practicality of the lesson plan, module and student worksheets were as follows in Table 3:

Table 3: Data from the Questionnaire on the Practicality of Learning Devices

Product	Rated Aspects				Average	Criteria
	Presentation	Usage	Readability	Time		
Lesson Plan	84%	78%	79%	78%	75%	Practical
Module	83%	80%	83%	80%	78%	Practical
Student Worksheets	80%	78%	75%	80%	78%	Practical

Effectiveness of STEAM-C-based Learning Tools

Furthermore, 74 students participated in the field test. In the field trials, students were given tests of creative thinking skills after they had completed their studies. As evidenced by the achievement of four indicators of creative thinking ability, learning can encourage students to think creatively. To test the effectiveness of the developed learning tools, manual calculations were used, namely, the formula effectiveness of the Normalised gain test (N-Gain) with the aim of finding out the increase in students' creative thinking skills (Hake, 1999). The following are the test results and indicators for creative thinking ability (Table 4).

Table 4: Students' Creative Thinking Ability Test Results

Score	Frequency	Category
g > 0.7	17	High
0.3 < g < 0.7	46	Medium
g < 0.3	11	Low

Table 5 shows the results of students' creative thinking ability tests based on indicators of creative thinking ability.

Table 5: Achievement of n-gain Scores on the Criteria for Creative Thinking Skills

Indicators	n-gain Scores	Criteria
Fluency	0.76	High
Flexibility	0.58	Medium
Elaboration	0.62	Medium
Originality	0.67	Medium

Discussion

In line with the research results, the developed STEAM-C integrated learning device meets the valid, practical and effective criteria for improving creative thinking skills. Furthermore, the learning was carried out using a project-based learning model with a STEAM-C approach that related to the surrounding culture, namely, the Masjid Kuno Taman. As a result, STEAM can increase student involvement in learning, creative thinking, student-generated innovation, student problem-solving skills and provide other cognitive benefits for students (Zubaidah, 2019; Mu'minah, 2021).

In addition to being an attraction for learning, culture can be a connecting tool for students to understand their learning material and get to know the local culture within the school environment. In culture-based learning, the learning environment will become a pleasant environment for teachers and students, allowing them to actively participate based on the culture they already know so that optimal learning outcomes can be obtained (Fahrurrozi, 2015). Learning that links to culture will change the learning environment to provide more fun and to foster active participation from students, so that optimal results are obtained and can provide many opportunities for students to show their curiosity and be directly involved in the process of creative analysis and exploration in order to find the answers they need, as well as becoming involved in the process of drawing different conclusions than others.

The learning tools developed could improve students' creative thinking skills. Of 76 students, 85% of them had creative thinking abilities that fell into the medium-high category. In addition, when viewed from the four indicators of fluency, flexibility, elaboration and originality, the n-gain score showed in the high and medium categories. Project-based learning activities can encourage students to think creatively (Fathoni et al., 2018) and contribute to shared outcomes so that they have elements of a learning experience with active reflection and conscious involvement (Kokotsaki et al., 2016). Students who think creatively can enhance their positive attitude without experiencing discouragement when answering math problems and be able to see various alternatives in solving other problems (Rahayu et al., 2019; Magelo et al., 2020).

Implications for Learning Design

The STEAM-C integrated learning device in Masjid Kuno Taman met the aspects of validity, practicality and effectiveness in improving students' creative thinking skills. By utilising the culture that exists within the students' environment, teachers can shape creative learning and other fun activities by linking several mathematical concepts. The development of students' creativity can be done through the integration of mathematics content and culture to foster students' ability to develop cultural heritage according to the present context using mathematical creative thinking skills. Students are expected to see math applications and connections not only in other disciplines but also in the real world. Teachers can develop local culture-based learning to make learning more fun and more meaningful for students. The limitation of this research is that learning takes relatively longer than the usual time. Future research can bring culture into the classroom by presenting it with technology-based tools.

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