



Development of STEM-Based Educational Games As Differentiated Learning Media to Improve Students' Creative Thinking Skills

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Abstract: This study aims to analyze the validity of developing STEM-based educational games on force and movement material to improve junior high school students' creative thinking skills. This research method used research and development with the ADDIE model involving three stages: analysis, design, and development, but each stage was always evaluated. The research subjects consisted of 32 students of SMPN 3 Jember class VII and two teachers. The research object was an analysis of the needs of teachers and students in developing STEM-based educational games. The data collection instrument was a validation sheet with data analysis techniques in the research, including validity test analysis techniques and questionnaires to determine needs analysis. The research results obtained were an analysis of teacher needs of 100% and an analysis of student needs of 80% to develop the quality of STEM-based educational game learning media. Data analysis of the average assessment score of the three expert validators was 93%, showing that the category was very valid so that STEM-based educational game development products can be used, but there are slight revisions.

Article History

Received: 11-09-2023
Revised: 26-11-2023
Accepted: 17-12-2023
Published: 10-01-2024

Key Words:

Educational Games;
STEM; Differentiated
Learning Media; Student
Creativity.

How to Cite: Hidayati, S., Hariyadi, S., & Putra, P. (2023). Development of STEM-Based Educational Games As Differentiated Learning Media to Improve Students' Creative Thinking Skills. *Jurnal Paedagogy*, 11(1), 1-14. doi:<https://doi.org/10.33394/jp.v11i1.9589>



<https://doi.org/10.33394/jp.v11i1.9589>

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Introduction

In the 21st century, global competency demands consist of critical thinking, creativity, collaboration and communication (4C) (Hartati, 2020). The 21st century also requires an important role for students' skills in creative thinking to improve the quality of education in various fields of learning, one of which is science (Rafik et al., 2022). According to research results from The Global Creativity Index (GCI) in 2015, the creative thinking skills index for students in Indonesia was low. Indonesia is ranked 115th out of 139 countries that have been studied, making the level of creative thinking skills achieved by Indonesia quite far behind compared to other countries in Southeast Asia (Florida et al., 2015; Kartika & Hastjarjo, 2021).

The world of education in the currently developing curriculum, namely an independent curriculum, is required without any burdens related to the era of society 5.0 which makes humans the main subject in controlling technological and scientific progress. The current development of the independent curriculum implements more flexible learning because it adapts to student needs (Purwanto & Gita, 2023). The benchmark for the success of the independent curriculum is seen from the profile of Pancasila students, one of which is the creative aspect of students, where teachers can provide motivation and increase students' creativity in finding solutions to problems (Samsinar et al., 2023).

According to Herwina (2021), suitable learning is used to adjust students' learning needs so that students can fulfill one aspect of the Pancasila student profile, namely differentiated learning. Differentiated learning provides accommodation to meet students'



unique and diverse learning needs in the form of students' interests, learning styles and learning readiness so that students are more motivated and skilled in creative thinking. (Miqwati et al., 2023). Differentiated learning has a strategy consisting of content differentiation, process differentiation and product differentiation. Based on research Nuryani et al. (2023) the differentiated learning process can improve students' creative thinking skills reaching 87.94% with very good criteria. In differentiated learning, the process is considered more effective in meeting the needs of students' learning styles so that ideas and information processes are better accommodated (Halimah et al., 2023).

Based on research Nabila (2023) dan Yani et al. (2023) In the differentiated learning process, many teachers experience difficulties in implementing it, and teachers are still not varied in providing learning media that suits students' different learning styles. This learning media can increase students' interest in learning in improving students' creative thinking skills according to the Pancasila student profile in differentiated learning (Astria & Kusuma, 2023). Learning media in the form of educational games can overcome students' learning problems while playing Wulandari et al. (2017) and can also improve students' creative thinking skills (Widiyanto & Yuniarta, 2021).). It makes many students feel enthusiastic about learning, not bored and can eliminate verbalism in learning because the learning atmosphere will be more enjoyable with various skills. The design of educational games collaborates with educational elements that can stimulate students' thinking power, focus students' concentration, and train students' abilities in solving problems using various strategies (Prasetyo et al., 2020; Najuah et al., 2022).

This statement is in accordance with research Mastoah et al. (2022) that educational games are created to help students learn while playing by stimulating problems and animations so that they can improve creative thinking skills, learning motivation, and memory that can last a long time in storing information (Humaida & Suyadi, 2021). STEM-based researchers will further develop educational games in Learning. STEM is learning that integrates Science, Technology, Engineering, and Mathematics to build 21st-century skills by current developments in the current era of globalization (Erlinawati et al., 2019). Based on research Putra (2023) Learning using educational games combined with STEM can increase students' interest in learning and thinking skills. Teachers and students provide positive responses to the learning process by implementing STEM-based educational games. The use of educational games in STEM learning is very relevant and has the potential to encourage students to have the ability to solve problems, experiment and create real projects so that they can build students' creative thinking skills that are in line with the profile of Pancasila students in differentiated learning (Zainil et al., 2023).

The current challenges of the 21st century curriculum also require students to have several skills that are appropriate to current life problems. Likewise, science learning does not only involve learning all about nature, including various facts, concepts and principles, but it is hoped that there will be a process of discovering phenomena around us (Wilujeng, 2018). Science learning material has fundamental concepts and explains many phenomena in everyday life, namely force and motion. Based on research Taqwa et al. (2020) The force and movement material mastered by students is very low and difficult to understand, because students' reasoning is not in accordance with scientific concepts that are connected to everyday life.

The latest development of educational game that I developed is related to STEM and differentiated learning. This STEM-based educational game is designed by adjusting STEM indicators and indicators of students' creative thinking skills in science learning on Force and

Motion material. This game was developed using the Smart Apps Creator application. In previous research Putra (2023) discussed the development of STEM-based educational games with the help of RPG Maker MV in Mathematics learning material on Building Flat-Side Rooms. Based on the description above, this study aims to develop learning media in STEM-based educational games to support the learning process in improving students' creative thinking skills.

Research Method

This research method used research and development with the ADDIE model to produce products and the effectiveness of a product (Saputro, 2017). According to Branch (2009) ADDIE is the use of a development model in the right circumstances to develop learning products/resources in education. According to Tung et al. (2017) The ADDIE model has five stages: Analyze, Design, Develop, Implement, and Evaluate. This research was carried out more simply, involving three stages: analysis, design, and development. However, each stage was always evaluated according to the scheme in the ADDIE model. Due to limited time, energy or other resources, it becomes a limiting factor in carrying out research or development at all stages.

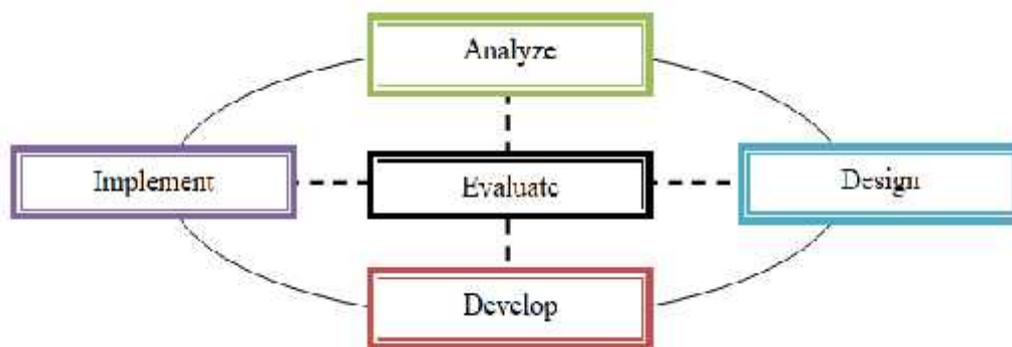


Figure 1. ADDIE Model Schematic

The research subjects used were 32 class VII students at SMP Negeri 3 Jember. The data collection instrument is a validation sheet with data analysis techniques in the research, including validity test analysis techniques. It is the aim of this research, namely, to develop STEM-based educational games that are valid to be applied during learning.

The validity test to measure the validity of developing STEM-based educational games uses a validity sheet which includes several criteria for assessing validity consisting of components of presentation, suitability of content, language, and suitability of images (Banjarani et al., 2020). Validation test results are classified based on validity criteria.

Table 1. Product Validity Level Criteria

No	Criteria	Validity	Validity Level
1.	85% < V	100%	Very valid, that it can be used without any revision.
2.	70% < V	85%	Valid, so it can be used with slight revisions.
3.	50% < V	70%	Less valid, so it is not recommended for use.
4.	25% < V	50%	Invalid, so it can't be used at all.

Source: (Rohma et al., 2022)

Results and Discussion

The word *rumangsa* means to feel, to realize. *Handarbeni* means to have (Mardiwarsito, 1993). It means to feel a sense of belonging. In a symbolic sense, the word



means the responsibility of a person who must understand that the task must be perceived and carried out as his own. Rumangsa melu handarbeni, in Indonesian, means to feel belonging, to take care of it, but still to do introspection, which leads to courage. So, the word that is

The results of the data obtained in this research are validation assessment data for the development of STEM-based educational games.

Analyze Stage

At this analyze stage, determine and collect information about basic problems that will become a reference for developing STEM-based educational games. The data or information that must be collected in this stage is needs analysis, student analysis, and learning material analysis. The needs analysis was carried out to analyze and determine the problems teachers face when conducting science learning at SMPN so that researchers can identify products that suit learning needs. Student analysis is carried out to analyze and know the characteristics of students so that they can adapt them to the product to be developed. The characteristics of students tend to have a low interest in learning, which affects their' creative thinking skills in studying learning material. Material analysis is carried out to determine learning materials by the curriculum implemented and the needs of students at school. The learning material used in this research is force and movement because students' reasoning is not in accordance with scientific concepts related to everyday life. Students' low mastery of concepts makes it difficult to understand the material.

The results of the questionnaire distributed via Google Form to students and teachers showed that they had implemented learning using technology-based learning media in the form of PowerPoint and learning videos from the internet. Teachers also provide learning to students with the help of worksheets and presentation of material from the teacher. However, some students still feel bored and fed up with learning, so students are less interested in learning. It causes researchers to plan the development of additional learning media to support the needs of students and teachers in teaching and learning activities. The results of the analysis of student needs and teacher needs regarding interactive learning media are in Table 2 and Table 3.

Table 2. Teacher Needs Analysis

No.	Indikator	Response	Amount	Percentage
1.	The quality of student learning in science learning needs to be provided with additional interesting learning media	Yes	2	100%
		No	0	0
2.	The use of STEM-based educational games is still rarely used	True	2	100%
		False	0	0
3.	Teachers' knowledge of STEM	Ever	1	50%
		Never	1	50%
4.	The application of STEM-based educational games to students is very necessary in learning activities	True	2	100%
		False	0	0
5.	Learning activities carried out every day are often still conventional	Yes	2	100%
		No	0	0

Based on the results of table 2, it shows that 100% of science teachers need to design additional learning media aimed at students in science learning activities. In line with the statement in an article that the development of learning media is very effective and worthy of being designed and used in learning activities. The designed learning media will attract students' attention in learning and increase students' interest to make it easier for students to understand learning (Ardiani, 2022). Supported by the article's statement that student learning process activities can appear more attractive to students because of the combination of media



displays with various additional image and animation features developed with technology to combine (Kuswanto & Radiansah, 2018). The teacher needs analysis data results showed that 100% said that teachers and students in science learning rarely used STEM-based learning media. The statement was supported by research that educational games still need to be improved and rarely used in learning even though many teachers have technological devices like Android cellphones, the internet, and laptops or computers (Suryanto, 2020). A teacher also experiences various difficulties in preparing technology-based media so that much time is spent studying. Implementing learning using STEM still makes teachers experience difficulties when using and developing technology aimed at students in class without being able to develop the educational media they have created. Many teachers have limited understanding of learning using STEM and how to integrate it into everyday teaching. Teachers also often have difficulty aligning lesson material with designing learning activities that fit the STEM approach (Firdaus et al., 2023).

In the results of the analysis of teachers' needs regarding their knowledge of STEM, the percentage is 50%: 50%, there is a balance between ignorance and possession of knowledge about STEM. The article supports this statement that teachers' knowledge about STEM is still low, giving rise to teachers' unpreparedness to implement learning using STEM media (Diana & Turmudi, 2021). Teachers need to know about STEM in learning media because it can keep up with current developments so that students can be more active and creative during learning activities (Hamidah & Ardiansyah, 2023). A solution can be designed to solve this problem by holding outreach regarding the development of various STEM learning to teachers at MGMP to achieve learning goals and support the learning process.

Furthermore, the results of the teacher needs analysis have a percentage of 100% in implementing artificial intelligence-based learning media for students in learning activities. The results of the latest teacher needs analysis show that every day 100% of learning activities are still conventional. Some teachers still carry out monotonous learning activities when delivering science learning material (Dwiqi et al., 2020). Teachers' use of learning resources is also still in the form of printed teaching materials so that students feel less able to use the application of technology-based learning media. It can make it easier for students to feel bored and fed up when following a lesson.

Table 3. Student Needs Analysis

No.	Indikator	Response	Amount	Percentage
1.	Students have difficulty understanding science learning because the learning media used is less interesting	True	26	86%
		False	4	24%
2.	Students want to get STEM-based games that can interest their learning	Yes	24	80%
		No	6	20%
3.	Student learning only with teacher explanations and PPT can make students bored and not understand the learning material	True	19	63%
		False	11	37%
4.	Students have an Android cellphone or laptop that can be used to support learning	Yes	28	93%
		No	2	7%
5.	Students want to learn to use STEM-based games to support science learning	Yes	24	80%
		No	6	20%

Based on Table 3, the analysis of student needs shows that as many as 86% of students may experience some difficulties in understanding science learning because the learning media used is less interesting. This statement follows an article that says that using



science learning media minimally or less optimally will affect the implementation of learning activities, so it does not attract students' interest and attention. Students become easily bored and fed up when learning begins (Ariyani & Ganing, 2021). Around 80% of students want to get artificial intelligence-based learning media that can attract their interest in learning. The foundation for the birth of STEM supports education, especially in science, with the increasing development of technology and educational progress (Sidabutar & Munthe, 2022). STEM can attract students' interest in learning because it has the ability to complete learning by analyzing problems in everyday life related to learning material.

The analysis of student needs showed that 63% of learning was limited to teacher explanations and PPT so students easily got bored and did not understand the learning material. According to the article's explanation, learning using the lecture method can make students bored more quickly, so they do not focus on paying attention to the teacher's explanation of the material (Zarkasi & Taufik, 2019). Sometimes, students must also pay attention to the teacher's explanation of the material before they joke and talk with their friends. As many as 93% of students have Android cellphones or laptops, which can be used to help students learn using other learning media besides books but can use internet sources. It can be an additional supporting component by designing STEM-based educational game learning media that supports students in learning science. In line with the article's statement that STEM can expand various diverse learning systems in education. STEM assignments can build a learning system by integrating several subjects, namely science, technology, engineering, and mathematics, which can be collaborated in technology or computer systems (Oktaviani et al., 2021).

Design Stage

The design stage was realized by selecting learning media that will be used to present learning material. The design stage is creating a learning plan by determining learning objectives, determining the preparation of tests, choosing appropriate learning strategies in the form of learning methods and media, and other relevant learning support sources (Mashuri & Budiyo, 2020). Next, researchers designed products that would be used in the form of components in STEM-based educational games. The learning device designs used by researchers are teaching modules, evaluation of students' creative thinking skills tests, and STEM-based educational games. The learning modules are prepared with a time allocation of 20 JP (Hardanie, 2021)(Budiyanti Dwi Hardanie, 2021), carried out face to face. Evaluation of students' creative thinking skills tests is adjusted to learning indicators and students' creative thinking skills. STEM-based educational games contain 4 menus (introduction, learning materials, games, and evaluation). The game menu has 3 STEM game levels: STEM 1, STEM 2, and STEM 3.

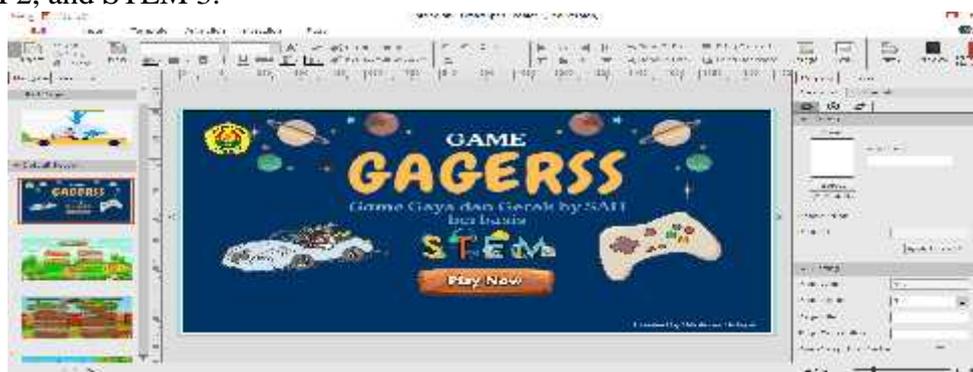


Figure 2. Game Design on SAC Applications

At this stage, assessment instruments were also designed, including a validity sheet used as a validity reference, an implementation sheet as a practical reference, and pre-test and post-test evaluation questions as well as student questionnaires used to test the effectiveness of the STEM-based educational game being developed. This assessment instrument tests the feasibility level of STEM-based educational games after they are developed and used in the learning process.

Develop Stage

This development stage makes the previously planned STEM-based educational game product design a reality. In accordance with statement (Firdaus et al., 2023) The development stage is the stage of realizing the product design into reality by developing the product. At this stage, trials are carried out before the product is implemented, namely by conducting an evaluation. The evaluation carried out was a formative evaluation which results in improvements in the development of the learning system. The development of STEM-based educational games were in accordance with the structural framework, systematic content, and appropriate presentation of questions and materials at the design stage. At this stage, references were used as guidelines in the making. The initial product produced from this stage would be validated by the validator.

Three validators, including expert validators, validated this STEM-based educational game product to determine whether the product created was well implemented or tested at the implementation stage. The validation results that the validator has assessed will be accompanied by suggestions for improving the product before testing on students. The validation questionnaire can be seen in the attachment section. The instrument used to validate products is made using a questionnaire in the form of a Likert scale. There are 4 points on the Linkert scale, namely 4 (Very Valid), (Valid), (Less Valid), and (Invalid). The reason for using the Likert scale is to consider obtain a clearer view of the respondents regarding the statements presented in the questionnaire (Indriani & Lazulva, 2020). The validation assessment carried out is included in the formative evaluation.



Figure 3. Game Cover and Title Display



Figure 4. Menu Display



Figure 5. Learning Objectives Menu Display



Figure 6. Let's Learn Menu Display



Figure 7. Developer Menu View



Figure 8. Let's Play Menu Display

The figure 3 shows the cover appearance of a STEM-based educational game containing the title and play button. The title of this STEM-based educational game is GAGERSS Game (STEM-based Style and Movement Game by SAH-Siti Anisa Hidayati). Figure 4 shows the menu features that students can choose randomly, including objectives, let's learn, developer profile, let's play, instructions, and quiz time. Figure 5 shows the learning objectives associated with indicators of students' creative thinking skills. Figure 6 shows the let's learn menu containing learning material that students can choose from, including force, motion and Newton's laws. Figure 7 shows the developer menu containing the developer profile of Siti Anisa Hidayati along with photos and logos from her campus.

Figure 8 shows the game menu containing game levels 1, 2, 3 with different activities at each level. This STEM-based educational game contains activity titles and client letters containing analysis of problems related to force and movement in everyday life. This section is structured by connecting indicators of students' creative thinking skills (He, 2017). Students are invited to choose the tools and materials they will use to assemble solutions in experiments flexibly. The activities in this game are adapted to the second indicator of students' creative thinking skills, namely flexibility. Students can arrange work steps in experiments randomly so that it can make students think about how to arrange work steps correctly and smoothly. The activities in this game are adjusted to the first indicator of students' creative thinking skills, namely fluency. Students can draw their solution designs with the solution shape they want. The activities in this game are adjusted to the third indicator of students' creative thinking skills, namely authenticity. Experimental videos also accompany this game to facilitate students with an audio-learning style.



STEM 1 game based on learning styles



Activity title 1 and client letter



Game tools and materials



Work steps



Figure 3. STEM Game display on the Let's Play menu

This STEM-based educational game section also contains the challenge of calculating the speed of a moving object. Students can find distance and time to obtain speed using a formula. The activities in this game are adapted to the third indicator of students' creative thinking skills, namely detailing.



Figure 4. Quiz Time display

Figure 10 shows quiz time to test students' knowledge of force and motion material. In this quiz time there are 10 quiz questions with multiple choice type which you can immediately find out the score after answering.

Validity of STEM-based Educational Games

The development of STEM-based educational games was assessed by 3 expert validators to determine the validity of a product as follows.

Table 4. Validation Results

No.	Assessment Aspects	Average Score (%)			Average (%)	Criteria
		Validator 1	Validator 2	Validator 3		
1.	Opening	95	95	90	93	Very valid
2.	Menu	92	92	100	94	Very valid
3.	Learning objectives	100	100	100	100	Very valid
4.	Let's learn	100	95	95	97	Very valid
5.	Let's play	70	78	78	75	Valid
6.	Developer	88	100	88	92	Very valid
7.	Instruction	94	94	94	94	Very valid
8.	Quiz	100	100	94	93	Very valid
Average Score		92	94	92	93	Very valid

Data analysis of the average assessment score of the three expert validators is 93%, showing the very valid category so that STEM-based educational game development products can be used, but there are slight revisions. Revisions were made in accordance with Figure 11 that in the description section for the three game activities, the description "STEM Game" needs to be added. Its function is so that students can more easily understand that symbols 1, 2, and 3 are different STEM game activities if they are clicked. This statement is in accordance with research Arifah et al (2019) said that educational games using Bilomatics are suitable to be applied as learning media during classroom learning activities. Arisandy (2021) explained that educational games had met the valid category after several revisions

were carried out taking into account validity criteria with the aim of developing educational game products. According to Fajar et al. (2022) The development of educational games using SAC software was assessed by expert validators as very high or very valid. However, there were still several notes from experts with the addition of moving animations.



Figure 5. Improvement of Validation Results

Conclusion

Based on the data analysis and discussion results, STEM-based educational games have proven valid in improving students' creative thinking skills in science learning on force and motion material in junior high school. The validity of the STEM-based educational game regarding the validation assessment from the third expert validator was 93% with very valid criteria, but there were slight revisions. STEM-based educational games that are valid and revised can be continued at the implementation stage by the ADDIE development model.

Recommendation

Recommendation aimed at teachers and students as well as other users can use Android and laptops to access STEM-based educational games. It is hoped that teachers can be a bridge between students and STEM-based educational games so they can learn while playing but can also increase students' skills in creative thinking.

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