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Development of PUME as an educational game to optimize students' creative mathematical thinking ability in solid geometry topics

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Abstract

This study aims to develop a learning medium in the form of a game used for practice questions through PUME in the Solid Geometry topic to optimize creative thinking abilities. The method used in this study is Research and Development (R&D) with the ADDIE model (Analysis, Design, Development, Implementation, and Evaluation). The participants for evaluating the feasibility of PUME included 4 media experts and 3 content experts consisting of lecturers and teachers, while the participants for assessing effectiveness were eighth-grade junior high school students from Cianjur district. The data collection techniques used in this study were a test of students' creative mathematical thinking abilities and expert judgment (validation by media experts, content experts, and student responses). The data analysis techniques used in this study involved qualitative data analysis (data reduction, data presentation, conclusion drawing) and quantitative data analysis in the form of percentage validation by media experts, content experts, and student responses using random sampling. The results of the study on the development of PUME as a learning medium for the Solid Geometry topic in the form of an educational game show that it can optimize students' creative mathematical thinking abilities. The feasibility level of PUME was rated as "very feasible," and the effectiveness of PUME was classified as "effective" for implementation in mathematics learning for the Solid Geometry topic in junior high schools. As for students' creative mathematical thinking abilities, 45% of the students were nearly able to optimize their abilities.

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1. Introduction

Mathematics subjects are held at all levels of education in Indonesia starting from elementary school to university level, aiming to foster and develop logical, analytical, systematic, critical, and creative thinking abilities, and the ability to work together for students (Nursyeli & Puspitasari, 2021). Creative thinking is one of the abilities that really needs to be developed through education in school subjects, one of which is in learning mathematics. The ability to think creatively in mathematics is very much used with the aim of utilizing students' creative thinking with the aim of arousing student interest and giving students breadth in making choices, asking questions, and solving a meaningful problem (Agustina & Sumartini, 2021). Mathematical creative thinking abilities in students in the current era can still be said to be low (Sanusi et al., 2020). In the context of geometry learning, creativity plays a crucial role in helping students visualize, explore, and discover geometric properties in a more meaningful way. The integration of creative approaches in geometry education not only enhances students' problem-

solving skills but also encourages them to develop innovative strategies in understanding spatial relationships and geometric structures (Fatihah et al., 2023; Sudirman et al., 2023).

Based on the results of the Survey in the field of the Program for International Student Assessment (PISA) in 2022. Experiencing a decline in learning outcomes internationally due to the pandemic, this shows that Indonesia is still categorized as a low country in having creative thinking abilities, even so Indonesia's ranking regarding mathematical literacy in PISA rose 5-6 positions compared to 2018. According to Kencanawati (2020) the results of the PISA study can be attributed to creative thinking abilities because PISA questions are contextual questions that demand reasoning, argumentation, and creativity in solving them. So the results of PISA research can reflect students' creative thinking abilities. This indicates that although Indonesia has shown slight progress in mathematical literacy, the development of students' creative thinking skills still requires significant attention. The complexity of PISA questions highlights the need for an educational approach that not only focuses on procedural knowledge but also encourages students to develop innovative problem-solving strategies. Strengthening creative thinking in mathematics learning can be a key factor in improving Indonesia's overall performance in future PISA assessments.

The development of creative thinking abilities is one of the main goals of national education, aiming to cultivate individuals who can generate new ideas and innovations (Binkley, 2012). In mathematics education, creative thinking plays a crucial role in enhancing students' fluency in generating ideas, detailing concepts thoroughly, and demonstrating flexibility in problem-solving (Widiyanto & Yuniarta, 2021). By fostering these abilities, students can develop a more positive perception of mathematics, making it less intimidating and allowing their creativity to be fully explored. Then the problem found related to building space material is that students are confused in solving the training problems given, because the formulas are very complicated and easy to confuse, accompanied by students' lack of understanding of how to work on problems using other methods, and students do not understand the problems given whether using the first or second method.

Students' difficulty in learning mathematics material is one of the main learning problems (Inayah et al., 2020). The problem that has a relationship with students' mathematical creative thinking ability is that the material for building space is that students are confused in solving the training problems given, because the formulas are very complicated and easy to confuse accompanied by students' lack of understanding of how to work on problems using other methods. The rapid development of ICT (Information Communication Technology) at this time, as evidenced by the behavior of people who really like to use high-tech equipment. The increasing number of people who own and use mobile devices, opens up opportunities for the use of mobile technology devices in the world of education (Sadiyyah et al., 2019). It is quite clear that learning media in the form of games used for practicing questions in education using technology is needed (Septian et al., 2020).

One of the strategies that can be used to train students' creative thinking abilities in mathematics education is by using education games, because education games can improve creative thinking abilities, and can improve student learning outcomes and increase student knowledge (Sanusi et al., 2020). Students' pleasure in the world of technology today, especially in games, is very large, almost all students have technological equipment to play games including laptops, cellphones, and other technological equipment, because of this, teachers today must be able to keep up with the growth of the current technological era, where subjects that are generally boring turn into subjects that are fun and liked by students by using education games in their learning (Prambudi & Yuniarta, 2020).

Learning media in the form of games used for practice problems as an alternative solution to problems that can improve students' mathematical creative thinking abilities, previous researchers conducted research on high school students with row and series material (Sanusi et al., 2020). A learning media in the form of games used for problem practice is very influential on the learning process, therefore previous researchers aimed to describe the development steps and see the feasibility of a smartphone-based edutainment game used as a learning media in the form of games used for problem practice oriented to students' creative thinking (Mahfi et al., 2020).

The differences between this research and previous research, (Widiyanto et al., 2021) include previous research using an android-based education game that can only be accessed using a cellphone but this education game can be accessed anywhere, be it using a cellphone or laptop, this game can make

it easier for teachers to provide practice questions to students and all student grades are automatically listed in the game, and the game used in this study is called (PUME) Puzzle Make Easy with material for building space. The advantage of this game for teachers is that it can make it easier for teachers to give practice questions to students without having to write questions on the blackboard and this PUME will automatically recap the values of student training results without having to collect the results one by one, and the advantage for students is that it provides a new atmosphere in doing math practice questions, and can directly train students' speed, accuracy, and creativity.

The differences found regarding education games on the material of building space in this study include students being able to train more speed and creative thinking, if previously in mathematics subjects on the material of building space was boring because it was only counting and counting now mathematics subjects on the material of building space can be more exciting because it is more challenging and cultivates students' creativity abilities in games so that novelty is found in this study.

Based on the literature study on the previous researcher's study, it is necessary to construct learning media that can develop students' mathematical creative thinking abilities in order to create meaningful learning for students. Learning media in the form of games as media used during learning, can increase love while facilitating students' mathematical creative thinking abilities. From the description above, the researcher is interested in conducting research on students' mathematical creative thinking abilities by using PUME as an education game on the material of building space. This research aims to develop learning media in the form of games used for problem practice through PUME to optimize students' mathematical creative thinking abilities and to determine its feasibility and effectiveness. Based on these objectives, the research seeks to answer the following questions: (1) How can PUME be developed as a learning medium to enhance students' mathematical creative thinking abilities? (2) How feasible is PUME as an educational game for learning solid geometry? (3) How effective is PUME in improving students' mathematical creative thinking abilities?

2. Method

2.1 Research Design

This study adopts the ADDIE model (Analysis, Design, Development, Implementation, and Evaluation) (See Figure 1), which is a systematic and structured instructional design model. The first stage is Analysis, where the researcher identifies the needs of students and teachers related to game-based learning media, specifically to enhance creative mathematical thinking abilities in solid geometry topics. The analysis also includes identifying challenges in mathematics learning at the school level that can be addressed through the use of game-based media.

In the Design phase, the researcher creates the game flow and interactive features that aim to increase student engagement. This design involves creating questions that stimulate creative thinking as well as developing evaluation instruments in the form of tests to measure students' creative mathematical thinking and questionnaires to assess the feasibility and effectiveness of the developed learning media. The Development phase involves creating the PUME prototype, which is then validated by media and material experts to ensure it aligns with the learning objectives.

After the prototype is completed, the Implementation phase involves testing the game on students at SMP Negeri 1 Karangtengah. During the implementation, data on student responses and the effectiveness of the game are collected through tests and questionnaires. Finally, in the Evaluation phase, the data obtained from the trials are used to make improvements and adjustments to the game to ensure that PUME optimally enhances students' creative mathematical thinking abilities.

2.2 Participants

This study involves two main groups of participants: media experts and material experts, as well as students from SMP Negeri 1 Karangtengah. The four media experts, who are skilled in digital media and game design, assess the feasibility of the developed game. The three material experts, consisting of a mathematics education lecturer and two mathematics teachers, assess the effectiveness of the game in delivering geometric content in a creative and understandable manner. These experts were selected due to their deep knowledge of educational media and the subject matter being taught. The other participants are the 29 students from SMP Negeri 1 Karangtengah, who were selected using a random sampling technique. These students serve as the target participants for the trial phase to observe how they interact

with PUME and how it affects their creative mathematical thinking abilities in solving solid geometry problems. The random sampling technique was used to ensure that the sample was representative, allowing the findings of the study to be generalized.

2.3 Data Collection

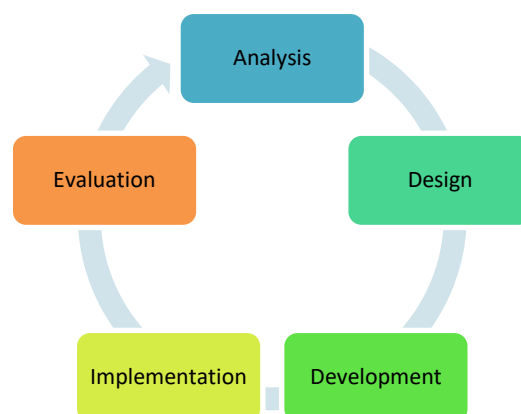
Data in this study were collected using several techniques. First, to measure students' creative mathematical thinking abilities, a creative mathematical thinking test was administered before and after the use of PUME. This test was designed to evaluate students' abilities to generate new ideas, solve problems in unconventional ways, and explore various possible solutions. In addition to the test, questionnaires were distributed to three different groups of respondents. The questionnaire for media experts aimed to assess the feasibility of the design and interactive features in PUME. The questionnaire for material experts was used to evaluate the effectiveness of PUME in helping students understand solid geometry content and to determine whether the game enhanced students' creative thinking in solving mathematics problems. The final questionnaire for students was given to gather their feedback on using the game for learning, specifically on its impact on their creative mathematical thinking abilities. Besides the questionnaires, observations were made to record how students interacted with the game during the learning process. The researcher observed how students solved problems in the game and how they engaged in group discussions or collaborative tasks. Interviews with teachers and students were also conducted to gather qualitative data on their experiences with PUME.

2.4 Data Analysis

The data collected from this study were analyzed using both quantitative and qualitative descriptive methods. The quantitative data from the creative mathematical thinking tests were analyzed using descriptive statistics, such as mean, standard deviation, and comparison tests to assess the differences in students' scores before and after using PUME. This analysis aimed to determine the extent to which PUME could enhance students' creative mathematical thinking abilities. The data from the questionnaires were analyzed using a Likert scale to assess the feasibility and effectiveness of PUME from the perspectives of media experts, material experts, and students. This analysis provided insights into the quality of PUME as a game-based learning media. For qualitative data, the results of the interviews and observations were analyzed using content analysis to identify key themes related to students' experiences with PUME and how the game affected their creativity in learning mathematics. Feedback from students and teachers was also used to identify potential areas for improvement in the game's design for future development.

Figure 1

Stages in ADDIE



3. Results and Discussion

3.1 Results

The results of this study include the form of PUME education game is a learning media in the form of games used for practice questions developed in this study with a link format that can be accessed on smartphones and easily accessed via google chrome for free. The results of research from experts in

developing PUME conducted in this study are an analysis of the feasibility of learning media in the form of games used for practice questions developed. PUME validation was assessed by media experts conducted by 4 media experts. The aspects assessed by media experts are instructional quality and technical quality. The percentage of the results of the evaluation score of the development of PUME as a learning media in the form of games used for practice questions based on instructional quality has a percentage value of 87.5% and the percentage of evaluation value based on technical quality is 82.69%. The results of the media assessment by experts are as follows:

Table 1.

Results of Media Assessment by Media Experts

Criteria	Result Score	Maximum Score	Total
Instructional Quality	28	32	87.5%
Technical Quality	172	208	82.69%
Total	200	240	83.33%

Based on Table 1, the results of the media expert validation indicate an average percentage value of 83.33%, which falls into the very feasible category. This suggests that the developed learning media is considered highly suitable for use in educational settings. The validation results are broken down into two key aspects: instructional quality and technical quality. The instructional quality received a percentage of 87.5%, indicating that the educational content and design were well-received, while the technical quality scored 82.69%, reflecting a positive evaluation of the media's technical aspects, including usability and functionality.

Further details regarding the instructional quality and technical quality are provided in Tables 2 and 3. These tables offer a more in-depth breakdown of the specific criteria assessed by the media experts, showing the strengths and areas for potential improvement in the educational game. The high ratings in both aspects suggest that PUME is well-aligned with the desired standards for effective learning media, but continuous refinement based on expert feedback will ensure its continued effectiveness and relevance in educational practice.

Table 2.

Results of Instructional Quality Assessment by Media Experts

Criteria	Result Score	Maximum Score	Total
Language	28	32	87.5%
Total	28	32	87.5%

Table 3.

Results of Technical Quality Assessment by Media Experts

Criteria	Result Score	Maximum Score	Total
Writing/Text	52	64	81.25%
View	52	64	81.25%
Technical Programming	41	48	85.41%
Navigation	27	32	84.37%
Total	172	208	82.69%

From Tables 2 and 3, it can be seen that PUME as a learning media in the form of a game was evaluated positively by the respondents, indicating that the game is easy to operate and meets user expectations. This ease of use is essential for ensuring that students can focus on the learning content without being distracted by technical difficulties. The respondents' feedback suggests that PUME's user interface and overall design align with the needs of the users, making it an accessible tool for enhancing students' mathematical skills, particularly in solving solid geometry problems.

The content within PUME is grounded in mathematics, specifically targeting solid geometry topics. The validation of this content was carried out by three material experts, who assessed the game based on two critical aspects: instructional quality and the quality of content and objectives. The material experts evaluated how well the game's content supported the learning objectives and its ability to

promote students' understanding of the subject matter. The evaluation scores for these aspects reflect a strong alignment with educational standards and the potential effectiveness of the game in improving students' mathematical creative thinking.

According to the evaluation results, the instructional quality of PUME received a score of 86.11%, indicating that the game's educational design is of high quality and effectively supports learning. Meanwhile, the quality of content and objectives received a slightly higher score of 86.66%, suggesting that the content is not only aligned with educational goals but also effectively designed to engage students in meaningful learning. These results highlight that PUME meets the expected standards for both instructional quality and content, demonstrating its potential as an effective tool for teaching mathematics in a creative and engaging way.

Table 4.

Results of Media Assessment by Material Experts

Criteria	Result Score	Maximum Score	Total
Instructional Quality	31	36	86,11%
Content and Objective Quality	52	60	86,66%
Total	83	96	86,45%

Table 5.

Results of Instructional Quality Assessment by Material Experts

Criteria	Result Score	Maximum Score	Total
Display	31	36	86,11%
Total	31	36	86,11%

Table 6.

Results of Content and Purpose Assessment by Material Experts

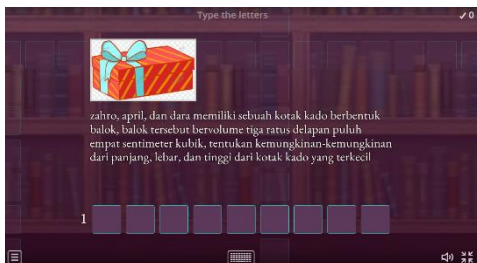
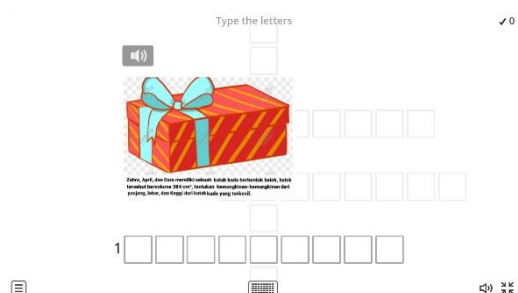
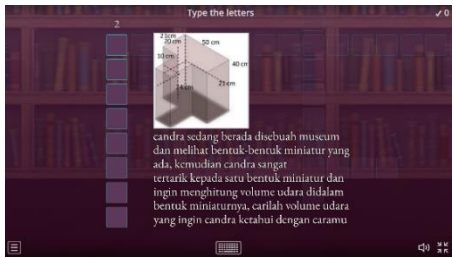
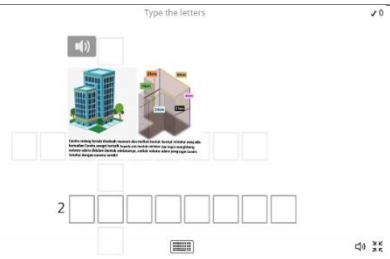
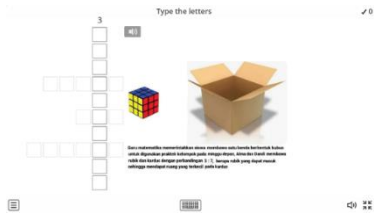
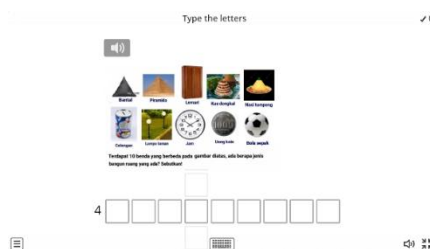
Criteria	Result Score	Maximum Score	Total
Material	52	60	86,66%
Total	52	60	86,6%

In the instructional quality assessment, there is one component that is assessed, namely the display where this aspect gets a score of 86.11% which is obtained by dividing the validator's empirical score by the maximum score. From the aspects assessed in the media developed, this is included in the very feasible category. This shows that PUME as a learning media in the form of a game used for practicing this question is easy to use by users or respondents.

In the quality of content and objectives, there is a material assessment criterion of 86.66% which is obtained from the empirical score of the validator divided by the maximum score so that the aspects assessed in the media developed are included in the very feasible category. The percentage of the average score of instructional quality, technical quality and quality of content and purpose is 86.45%. This shows that the material in PUME as a learning media in the form of games used for practicing this question is in accordance with the existing curriculum in Indonesia.

Furthermore, the revision stage is a stage carried out after the validity stage. Based on data analysis conducted on the results of media and material validation sheets assessed by four media and material expert validators, the percentage value is very feasible to be implemented. However, before being implemented, the media and materials on PUME were improved by revising according to the suggestions and input of expert validators. Some of the media revisions made in this study are described in Table 7.

Table 7.
PUME Revision

Before	After
 The mention of people's names must begin with a capital letter.	 The mention of people's names with capital letters is difficult to adjust to the suggestions.
 Add a sketch of the original building and give color to the lines in the miniature drawing.	 The original building sketch has been added and the color of the lines on the building frame in the question has been adjusted according to the suggestions.
 The questions have been adjusted to the age context of junior high school students.	 The questions have been adjusted to the context of the age of junior high school students in accordance with the suggestions.
 Change some objects and give the name of the object.	 The objects listed in the problem have been arranged and named according to the suggestions.

After going through the validation and revision process until the media was ready to be used, then the media was tested on respondents, namely students of SMPN 1 Karangtengah on April 25, 2024 in class VIII-G totaling 29 students. After the media was tested, the respondents were given an evaluation questionnaire that had been prepared based on predetermined aspects to be assessed until they obtained the results.

Table 8.

Results of Respondents' Questionnaires on Learning Media

Criteria	Result Score	Maximum Score	Total
Instructional Quality	468	696	66,23%
Technical Quality	195	232	84,05%
Content and Objective Quality	206	232	88,79%
Total	869	1160	74,91%

Based on Table 8. The percentage of the acquisition score of the evaluation of the development of PUME as a learning media in the form of games used for practice questions based on instructional quality has a percentage value of 66.23%, the percentage of evaluation values based on technical quality is 84.05% and the percentage of evaluation values for content quality and objectives is 88.79%.

3.2 Discussion

A learning media in the form of games used for question practice is very influential on the learning process, therefore previous researchers aimed to describe the development steps and see the feasibility of a smartphone-based edutainment game used as a learning media in the form of games used for question practice oriented to students' creative thinking (Mahfi et al., 2020).

The percentage of the average score of instructional quality, technical quality and content and purpose quality is 74.91%. The average score is converted according to table 4 and it is concluded that PUME as a learning media in the form of a game used for practicing this question according to students as respondents is included in the effective category. This result is obtained because the material presented in the PUME education game has been adjusted to the KD, indicators, and learning objectives to be achieved. In addition, the suitability of criteria with the needs and media developed will produce quality learning media according to learning objectives (Geni et al., 2020).

These results show that the media can be used in learning. So that PUME education game is used to find out students' mathematical creative thinking ability. Each question has different indicators of students' mathematical creative thinking ability, question number 1 has a fluency indicator, question number 2 has an originality indicator, question number 3 has a detail indicator, and question number 4 has a flexibility indicator.

In this study there were 29 students as respondents who would answer the following questions, out of 29 only a few students could answer the questions correctly per indicator. The results of student work with PUME from 29 students who were respondents only 19 students were able to answer this question, some students answered with brush answers and not in accordance with the commands ordered in the question, students have not been able to provide abilities in producing results of many different ideas, questions or answers, errors on student answer sheets.

This research was conducted to develop a product in the form of learning media PUME education game. One of the strategies that can be used to train students' creative thinking abilities in mathematics education is by using education games, because education games can improve creative thinking abilities, and can improve student learning outcomes and increase student knowledge (Sanusi et al., 2020). Creative thinking abilities with the help of technology are better in learning math Septian, et al, 2020). Based on these results, it can be said that learning using PUME on the material of building space is expected to be used optimally by teachers and other parties in different classes and provide many benefits for users.

4. Conclusion

Based on the description in the previous chapter, it can be concluded that this study is the result of the development of learning media in the form of games used for this practice question in the form of media with a link format that can be accessed on smartphones and easily accessed via Google Chrome for free. The development of learning media in the form of games used for this practice question is named PUME which is included in the very feasible category at the level of feasibility and also in the level of effectiveness PUME is included in the effective category, so that the learning media in the form of games used for this practice question is worthy of being used as a supporting media for student

learning that can be used anytime and anywhere. Likewise, the use of the PUME education game on students' mathematical creative thinking abilities, some students have almost been able to optimize it.

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