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Research Article

Gamification Of Mathematics Teaching Materials To Improve Problem-Solving And Critical Thinking Ability: The Experts' Assessment

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ABSTRACT

Gamification is a learning approach in which moving games or visualizations are specifically designed to teach specific skills to students so that the learning process motivates students to think and solve problems. This study aimed to measure the content validity of gamification-based teaching materials in the form of GEMAS games based on expert judgment. This study uses the ADDIE model of research and development. However, it is limited to only three stages: analysis, design and development, and an assessment by a team of experts using the Delphi technique. The research instruments used were the validation sheet for the critical thinking ability test using FRISCO theory, the validation sheet for the problem-solving ability test instrument with the Krulik and Rudnick indicators, and the game validation sheet. Data were analyzed descriptively. Based on the results of content validity data analysis related to GEMAS games, it was found that the criteria in the context of problem-solving skills and critical thinking skills were 90.20% fulfilled, and the criteria for fulfilling game content reached 94%. The data shows that the criteria for assessing the feasibility of the GEMAS game are 92%. Thus, the gamification-based teaching material in the form of the GEMAS game has been developed as an assessment in a very valid category and is suitable for use in learning.

Keywords: Gamification, Games, Problem Solving, Critical thinking, FRISCO, Krulik and Rudnick.

Introduction

The results of the 2015 TIMSS and 2018 PISA surveys show that the ability of high school students in Indonesia in the cognitive domain of application and reasoning is still below 25% (Hadi & Novaliyosi, 2019). These results show that the average high school student in Indonesia needs help to apply their basic skills correctly and extract relevant information from a single literary source (Pratiwi, 2019). The average high school student in Indonesia can only recognize several basic facts but cannot communicate, link various topics, and apply complex and abstract concepts in mathematics as a form of problem-solving abilities and critical thinking skills (Hadi & Novaliyosi, 2019). In addition, the results of everyday learning in class still need to be better for mathematical problem-solving skills (Hidayat & Sariningsih, 2018). Likewise, in mathematical critical thinking skills (Karim & Normaya, 2015), reasoning and proof, oral and written communication represented in the form of writing, drawings, mathematical expressions, as well as connections and representations from students when learning mathematics (Abdullah, 2013; Aminah, Wijaya, & Yuspriyati, 2018; Hodiyanto, 2017). These facts contradict the demands of the 21st century, which require graduates to have many skills, including problem-solving and critical thinking. Among the triggers is the existence of learning mathematics, which does not encourage students to improve their problem-solving abilities (Gunantara, Suarjana, & Riastini, 2014; Nofiyanti & Tatsar, 2023) and critical thinking (Prihartini, Lestari, & Saputri, 2016) . Learning carried out in class is generally still focused on things that are fundamental, theoretical, and yet to be applicable. This situation is not in accordance with (Pacific Policy Research Center, 2010) which suggests that in facing global challenges, the school curriculum should be transformed to produce graduates who are able to think critically,

are proficient in problem solving, collaborate, and have the innovation skills needed for success in the era of globalization, such as mastery of 21st century skills.
The implementation of learning that places more emphasis on mastering 21st century skills can be done one way through the Gamification technique. However, there is no specific research related to gamification in mathematics teaching materials that facilitates the improvement of students' mathematical critical thinking and problem-solving abilities. Therefore, this research focuses on developing gamification-based junior high school mathematics teaching materials to improve problem-solving skills and critical thinking. The quality is measured based on content validity, practicality, and classroom learning effectiveness. However, the discussion in this article is limited to measuring the content validity of gamification-based math teaching junior high school materials products based on expert judgment.

Literature review

According to Trilling and Fadel, 21st century skills (Hadinugrahaningsih et al., 2017) are placed into three categories: 1) Learning and innovation skills which include critical thinking and problem-solving, communication and collaboration, creativity and innovation; 2) Skills in using information technology and media which include information literacy, media literacy and information and communication technology (ICT) literacy; and 3) Life and career skills that include flexibility and adaptation, initiative and self-direction, social and cross-cultural interaction, productivity and accountability, and leadership and responsibility. Therefore, according to Nichols (Zubaidah, 2016), learning that emphasizes the mastery of 21st century skills has four basic principles. These use a planned approach to students, facilitating students to learn collaboratively, and learning is linked to everyday life, and learning facilitates students being involved in the environment.
The ability to solve problems is the ability to solve non-routine problems based on basic knowledge and mentality in the process of solving these problems (A. Kurniawan, Setiawan, & Hidayat, 2019). The ability to solve problems is a cognitive and complex thinking ability which includes the activities of analyzing, analyzing, reasoning, predicting, evaluating, and reflecting on information and previous knowledge that is implemented in producing alternative solutions or in new and unfamiliar situations situations (Amam, 2017; Indriyani, Nurcahyono, & Nur, 2018; Lestari, Purwanto, & Sakti, 2019; Ulya, 2016). The problem-solving ability indicator used in this study is the Krulik and Rudnick indicator, which describes a detailed heuristic pattern consisting of five continuous problem-solving steps. The stages are reading and thinking, exploring and planning, choosing a strategy, finding answers, and pondering and extending. This heuristic pattern is called a continuum; for example, reading and exploring can be done simultaneously through thinking activities. Likewise, at the same time, when the individual is carrying out the exploration stage, he is also included in the stage of selecting the strategy to be used (Shodiqin, Sukestiyarno, Wardono, Isnarto, & Utomo, 2020).
The ability to think critically is a process used to make reasonable decisions to obtain truth that is considered good. This ability involves prior knowledge, mathematical reasoning, and using cognitive strategies in generalizing, proving, or evaluating mathematical situations reflectively (Abdullah, 2013). According to some experts, indicators of critical thinking skills include: (1) generalizing, (2) identifying, (3) formulating problems into mathematical models, (4) deducing using principles, and (5) providing further explanations (Paradesa, 2017). Perkins & Murphy also put forward four indicators of critical thinking skills: clarification, assessment, conclusion, and strategy determination (Noor, 2019). Ennis put forward the indicators for critical thinking skills used in this study (Ennis, 2011; Fridanianti, Purwati, & Murtianto, 2018), namely FRISCO (Focus, Reason, Inference, Situation, Clarity, and Overview). Focus is the ability to determine the focus of the given problem. The reason is knowing the reasons for or against decisions based on relevant situations and facts. Inference is an activity of making reasonable and justifiable conclusions; Situation is the activity of applying previously owned knowledge concepts to solve problems in other situations. Clarity is the ability to explain the meaning or terms used. Furthermore, an overview checks or re-examines the problem-solving steps (Wicaksono & Prihatnani, 2019).
There is a connection between critical thinking and problem-solving. In students' problem-solving activities, students think to understand the concepts correctly to obtain the right solution. In more detail, Mahardiningrum stated that at the stage of understanding the problem, students must have the ability to interpret it to understand the problem given precisely. In addition, students must also have evaluation skills to evaluate the correctness of their understanding of the problem. Furthermore, critical thinking skills are also needed in compiling and determining a problem-solving plan. At the stage of the problem-solving plan, students explore all the concepts and procedures they have learned to solve problems correctly. Thus, indicators of critical thinking skills are needed, especially in the explanation section. From understanding the problem to re-examining the results obtained, critical thinking skills are needed to test the truth of these results. So, it can be seen that learning mathematics by solving problems will train students to think critically (Mahardiningrum & Ratu, 2018).
In line with Mahardiningrum, Saputra (H. Saputra, 2020) also suggests that critical thinking involves inductive thinking skills such as recognizing relationships, analyzing open-ended problems, determining cause and effect, making conclusions, and considering relevant data. Meanwhile, deductive thinking involves solving

spatial and logical problems and distinguishing facts or opinions. Critical thinking contains mental activity in terms of solving problems, analyzing assumptions, giving rationale, evaluating, conducting investigations, and making decisions. The ability to search, analyze and evaluate information is essential in decision-making. People who think critically will seek, analyze, and evaluate information, make conclusions based on facts and then make decisions. Thus, the two opinions make it clear that there is indeed a link between critical thinking skills and problem-solving.

The implementation of learning that places more emphasis on mastering 21st century skills can be done one way through the gamification technique. Gamification is a learning approach where games or moving visualizations are specially designed to teach specific skills to students so that the learning process motivates students to think and solve problems (Farida, 2018; Jusuf, 2016; Prabawa, 2017; Prambayun, Suyanto, & Sunyoto, 2016; Pujakusuma, Haryanto, Wirandhanu, & Pramudya, 2018). Gamification, first coined by game designer Nick Pelling in 2002, is defined as using game design elements in non-game contexts to enhance entertainment, target behaviour, and interaction (Yildiz, Topçu, & Kaymakci, 2021). Gamification is not about turning certain activities into games but redesigning those activities to be more fun and interactive (Wang, 2015). One of the contexts in which Gamification can be applied is education. Gamification can be in the form of products, ways of thinking, processes, experiences, methods of design, and systems that are simultaneously involved in using game elements to solve non-game problems (Purwono, Setyawati, Nisa, & Wulandari, 2021; M. D. Saputra, 2022). Gamification has similarities with regular games in terms of playing a game. However, the concept of Gamification and games, in general, is quite different. Ordinary games are only limited to specifically designed entertainment starting from the rules, time, place, elements, and gameplay. Gamification is designed to attract someone to understand the context of the material contained in the Gamification (M. D. Saputra, 2022). Several studies have shown that using Gamification in the classroom can increase learning activities and motivation and effectively improve student learning outcomes (Nurjannah, Kaswar, & Kasim, 2021; Permata & Kristanto, 2020; Ristiana & Dahlan, 2021; Suarmini, 2019).

Previous research on gamification shows that motivation, task design, short-term tasks, game identities, and reward systems form the core of gamification (Hakak et al., 2019). In its development, four types of gamifications have been widely researched. The first type of gamification uses Computer Assisted Language Learning (Jueru, Ferrão, Vitória, & Silva, 2020). This type of gamification can be considered and created in different environments depending on gender, age, culture, individual preference, level of knowledge, and even status as a player from essential to professional level. The second type of gamification is web-based, which presents students with a gamified learning environment where an automatic scoring sub-system supports training in computer programming (Polito et al., 2021). The results showed that the participants appreciated the opportunity to use a gamification system that featured automatic program ratings and found that the system helped improve their programming skills. In addition, the participants proved to be quite involved in solving programming problems and interested in the gamified aspects of the system. Furthermore, the third type is design gamification adapted to the learning environment, which involves 'Battle of Morphology' by focusing on instructional activities and game design elements. This study's results reveal that gamification positively impacts cognitive learning outcomes and student motivation and affectivity better than face-to-face learning (Qiao, Yeung, Shen, & Chu, 2022). This study's fourth type of gamification is focused on online quiz games as game-based learning (Balakrishnan Nair, 2022). The implications of the results of this research are valuable insights into the benefits of gamification for improving the quality of online classes by contributing to aspects of student engagement, motivation, creative learning experiences, humanizing diversity, and inclusion, and encouraging appropriate employability skills.

Many gamification applications, such as Kahoot, Math Riddle, Math land, Sudoku, and others, can be applied in education. Apart from using existing applications, there have also been several studies that have designed and tested a gamification-based application, such as an application for tourism students called HegameApp, which can be accessed via a smartphone or desktop computer (Aguiar-Castillo, Hernández-López, De Saá-Pérez, & Pérez-Jiménez, 2020). The trial results show that this application has a positive impact, one of which is encouraging active and collaborative participation in the learning process (Aguiar-Castillo et al., 2020). In addition, Jodoi (Jodoi, Takenaka, Uchida, Nakagawa, & Inoue, 2021) developed applications to improve critical thinking skills. The developed application places questions from easy to difficult so that users do not give up at the first stage; create groups of three or four students and show the group's progress rating, which is calculated as the average grade of students in a group; displays the progress rating of each student; as well as limiting the maximum number of questions that must be answered per day. However, the results of his research showed no significant difference between before and after using the application.

Previous research on gamification has only focused on increasing student learning motivation (Omar, Ali, Adam, Adnan, & Saari, 2022), growing student learning outcomes (Polito et al., 2021; Qiao et al., 2022), communication and collaboration skills (Farooq, Hamid, Alvi, & Omer, 2022), routine problem solving (Hakak et al., 2019), participation and learning experience (Balakrishnan Nair, 2022), and increased academic performance (Polito et al., 2021). The existing educational games usually have a selection of characters, conflicts/problems to level up, material content, and strategies to complete the game as needed (Pangestu, Netriwati, & Putra, 2019), designed for developing problem-solving skills. Problem (Jodoi et al., 2021; Putra & Pamungkas, 2019). This study also developed a similar application, but more specifically related to

gamification in mathematics teaching materials which facilitates the improvement of students' mathematical critical thinking and problem-solving abilities. The difference between this research and previous research is that the application developed is to improve critical thinking skills or problem-solving and enhance both. In addition, games are designed not only to place questions from easy to difficult, but questions also direct students to form an understanding regarding the material being studied, and there are learning videos to confirm student understanding, and questions are available for reinforcement.

Research methods

This study uses the ADDIE model of research and development which has five stages, namely *Analysis, Design, Development, Implementation,* and *Evaluation* (Cahyadi, 2019) according to figure 1. However, the research stages in this article are limited to ADD. The research procedure is described as follows.

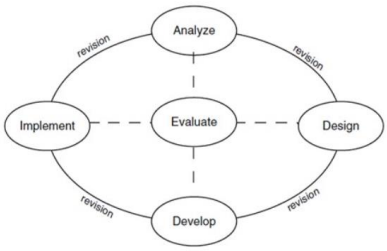

Figure 1. Stages of the ADDIE Model

Analysis

In this stage, preliminary studies are conducted, including field surveys, learning observations, and literature studies. This activity aims to map the problems faced by junior high school students in learning mathematics, analyze needs, design alternative solutions, and map research variables.

Design and Development

The activities carried out at this stage include: 1) reviewing the curriculum and content of junior high school mathematics learning materials; 2) designing learning scenarios in the form of level games adapted to indicators of problem-solving abilities and critical mathematical thinking; 3) making a layout or display design for teaching materials in the form of *a game* which can be seen in Figure 2; 4) designing learning video content that will be displayed in *the game*; 5) compiling and developing gamification-based teaching materials by predetermined layouts using *game applications*; and 6) conducting product evaluations to 5 Mathematics and ICT Education experts regarding the content of materials and games that have been developed.

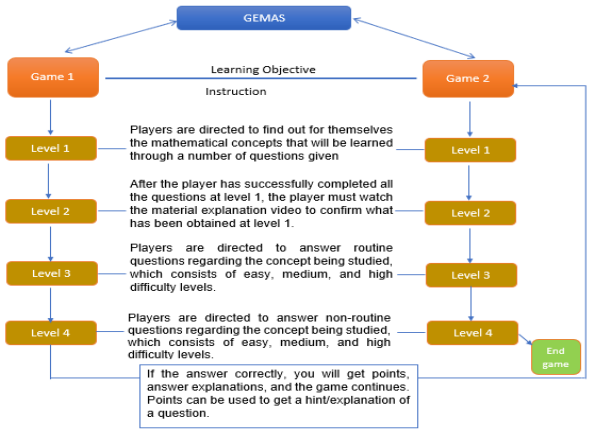

Figure 2. Hypothetical design of gamification of junior high school mathematics teaching materials.

The research instrument used was the validation sheet for the critical thinking skills test, the validation sheet for the problem-solving ability test, and the game validation sheet. The instrument validation sheets for problem-solving and critical thinking skills each consist of three aspects of assessment: content feasibility assessment, language aspect assessment, and assessment of the suitability of the items with indicators of problem-solving and critical thinking. In contrast, the game sheet consists of six parts: assessment of learning device aspects, assessment of visual communication aspects, assessment of game component aspects, assessment of material content, assessment of learning video content, and assessment of conclusion questions. The overall validity assessment uses a scale of 1-5, with categories including 1 (Very not good), 2 (Not good), 3

(Quite Good), 4 (Good), and 5 (Very good). The criteria are scale one if less than 20%, scale two if 21% -40%, scale three if 41% -60%, scale four if 61% -80%, and a scale of 5 if 81-100% of the criteria have been met (Lukman & Setiani, 2018).
Data analysis in this study was carried out descriptively. The procedure starts from 1) tabulating all data obtained from the validators on each indicator and sub-indicator available in the assessment instrument; 2) calculating the average total score of each indicator and sub-indicators; 3) converting the average score into a value with specific criteria or categories using guidelines for converting quantitative data into qualitative data as presented in table 1 (B. R. Kurniawan, Reyza, & Taqwa, 2018); and 4) calculate the overall assessment of the validity of the instrument developed with the following formula.

Assessment of the Overall Instrument

$\bar{x} = \frac{\bar{x_1}+\bar{x_2}+\bar{x_3}}{3}$

$\bar{x_1}$ = average problem-solving ability validation assessment
$\bar{x_2}$ = average assessment validation of critical thinking skills
$\bar{x_3}$ = average game validation rating

Table 1. Conversion of Assessment Score

Score Range	Category
$\bar{x} > 4{,}20$	Very Valid
$3{,}40 < \bar{x} \leq 4{,}20$	Valid
$2{,}60 < \bar{x} \leq 3{,}40$	Quite Valid
$1{,}80 < \bar{x} \leq 2{,}60$	Less Valid
$\bar{x} < 1{,}80$	Invalid

Statistical Analysis

The results of statistical data analysis in this study include data processing validation of test instruments for problem-solving abilities and critical mathematical thinking as content in the game being developed, as well as data processing validating the game's structure. The detailed explanation is described as follows.

A. Instrument Validation Results Test Problem Solving Ability and Mathematical Critical Thinking

Based on the validation results of the expert team, the content eligibility aspect has a value of 184 out of a total score of 200 or obtains an average validator rating of 4.60 on a scale of 5. That means 92% of the eligibility criteria for the contents test instrument have been met and are classified as very valid categories. Assessment of each indicator from content feasibility is presented in the following table.

Table 2. Assessment of the Feasibility Indicators of the Content

Criteria	**Indicators**	**Average**	**Average Per-Indicator**	**Category Validity**	**Percentage of criteria**
A. Conformance of the items with Phase D Learning Outcomes and Learning Objectives (SPLDV)	a. Completeness of the items	4.20	4.53	Very Valid	90.60% of the criteria in the indicators are met
	b. The breadth of the items	4.60			
	c. Depth of the items	4.80			
B. Accuracy of the items	a. Accuracy of concepts and definitions	5.00	4.53	Very Valid	90.60% of the criteria in the indicators are met
	b. Accuracy of pictures, diagrams, and illustrations	4, 00			
	c. Accuracy of mathematical terms	4.60			
C. date items	Using examples and cases found in everyday life	5.00	5.00	Very Valid	100% of the criteria in the indicators are met
On average		4.60		Very Valid	92% of the criteria in the indicators are met

In the feasibility aspect of using language, the validator team's assessment was 195 out of a total score of 225 or obtaining an average validator rating of 4.33 on a scale of 5. That means 86.60% of the criteria feasibility of

using language in the test instrument have been fulfilled and classified as a very valid category. The assessment of each indicator from the feasibility aspect of using language is presented in table 3.

Table 3. Evaluation of indicators of the appropriateness of using language

Criteria	Indicators	Average	average Per-indicator	Category Validity	Percentage Criteria
A. Straightforwardness	a. Accuracy of sentence structure	4.00	4.07	Valid	81.40% of the criteria in the indicator fulfilled
	b. Standard terms	4.20			
	c. Understanding messages or information	4.00			
B. Dialogical and Interactive	Ability to motivate students	4.60	4.60	Very Valid	92% of the criteria in the indicators are met
C. Communicative	Understanding of messages or information	4.60	4.60	Very Valid	92% of the criteria in the indicators are met
D. Conformity with the development of students	a. Conformity with the intellectual development of students	4.60	4.60	Very Valid	92% of the criteria in the indicators are met
	b. Conformity with the level of emotional development of students	4.60			
E. Conformity with the rules of language	a. Grammatical accuracy	4.20	4.20	Valid	84% criteria in the indicator are fulfilled
	b. Spelling accuracy	4.20			
Average		4.33		Very Valid	86.60% of the criteria in the indicator are met

Regarding the suitability of the Krulik and Rudnick indicators, the validator team's assessment was 1893 out of a total score of 2100 or obtained an average validator rating of 4.51 on a scale of 5. That means 90.20% of the item criteria are by the Krulik and Rudnick indicators and classified as a very valid category. The assessment of each indicator is presented in table 4.

Table 4. Assessment of Item Conformity Indicators with Krulik and Rudnick

Criteria	Indicators	Average Per Indicator	Average Per Criterion	Average Total	Category Validity	Percentage Criteria
Read and think *(read and think)*	The problem is analyzed and starts with critical thinking	4, 66	4.59	4.51	Very Valid	91.80% of the criteria in the indicators are met
	Test and evaluate facts	4.65				
	Define a question	4.75				
	Visualize *setting* physical	4.30				
	Explain and understand	4.65				
	Problems translated into the reader's language	4 .25				
	Connecting between parts of the problem	4.90				
Exploring and planning *(explore and plan)*	Analyzing data and determining whether the information obtained is sufficient	4.90	4.55		Very Valid	91% of the criteria in the indicator are met
	Eliminate distractors questions	4.30				
	Arranging data in the form of tables, pictures, models, and so on	4.30				
	Planning to find the development of answers	4.70				
Choosing a strategy *(select a strategy)*	Choosing a strategy	4.70	4.45		Very Valid	89% of the criteria in the indicators are met
	Solving problems using various variations of strategies	4.20				
Finding an answer *(find an answer)*	Doing the right estimation	5.00	4.50		Very Valid	90% criteria in the indicators are met
	Using a calculator or other technology to find an answer	4.00				
Reviewing and	Checking answers accurately to see whether the initial conditions of the	4.40	4,40		Very Valid	88% of the criteria in

discussing *(reflect and extend)*	problem have been met and if the questions have been answered correctly					the indicators are met
	Maximizing creative thinking	4,60				
	Alternative solutions must be found and discussed	4,00				
	Can change the problem by changing some initial conditions or interpretations	4,60				
	Find generalizations or mathematical concepts that underlie the situation if the process allows	4.40				
	Interesting variations of the original problem are to be formed and discussed	4.40				

On the health aspect, according to FRISCO theory, the validator team's assessment was 823 out of a total score of 900 or obtained an average validator rating of 4.61 on a scale of 5. That means 92.20% of the item criteria follow FRISCO theory and are classified as very valid categories. The assessment of each indicator of the FRISCO theory is presented in table 5.

Table 5. Assessment of Item Conformance Indicators with FRISCO Theory

Criteria	Indicator	Average Per Indicator	Average Criteria	Category Validity	Percentage Criterion
F *(Focus)*	Students understand the problems in the questions given.	4.70	4.70	Very Valid	94% of the criteria in the indicator are fulfilled
R *(Reason)*	Students provide reasons based on relevant facts/evidence at each step in making decisions and conclusions.	4.80	4.80	Very Valid	96% of the criteria in the indicator are met
I *(Inference)*	Students make the right conclusions.	4.30	4.45	Very Valid	89% of the criteria in the indicators are met
	. Students choose *reason* (R) to support the conclusions they make.	4.60			
S *(Situation)*	Students use all the information that is appropriate to the problem.	4.80	4.80	Very Valid	96% of the criteria in the indicator are met
C *(Clarity)*	Students use a more detailed explanation of what is meant in the conclusions that are made.	4.60	4.52	Very Valid	90.40% of the criteria in the indicator are met
	If there are terms in the problem, students can explain this.	4.60			
	Students give examples of cases that are similar to the problem.	4.35			
O *(Overview)*	Students research or re-check thoroughly from start to finish (produced by FRISCO)	4.40	4.40	Very Valid	88% of the criteria in the indicators are met
Average		4.61		Very Valid	92.20% the criteria in the indicators are met

Based on the four aspects of content validity assessment, the overall validity assessment of the test instrument for the problem-solving abilities and critical mathematical thinking of junior high school students with the FRISCO theory is $\underline{x} = \frac{4.60+4.33+4.51+4.61}{4} = 4,51$. These results indicate that 90.20% of the indicators of content validity have been fulfilled and are classified as very valid criteria.

B. GEMAS Game Validation Results

GEMAS games are assessed in several aspects, namely learning device aspects, visual communication aspects, game component aspects, material content assessment, learning video content assessment, and conclusion question assessment. The assessment of each GEMAS game component and indicator is presented in table 6.

Table 6. GEMAS Game Assessment

Criteria	Indicator	Average Per Indicator Average Per	Component	Category Validity	Percentage Assessment Criteria
Aspects of Learning Devices	a. *Maintainable* (can be maintained/managed easily)	4.40	4.56	Very Valid	91.20% criteria in the indicator fulfilled
	b. *Usable* (easy to use and simple to operate)	4.60			
	c. *Compatible* (learning multimedia can be installed or run in a predetermined application)	4.80			

	d. Learning multimedia operations (available with clear installation instructions and instructions for using the media)	4.20			
	e. *Reusable* (part or all learning media programs can be reused for the development of other learning media)	4.80			
Assessment of Visual Communication Aspects	a. Game applications are communicative, messages to be conveyed through game applications can be well received by the target audience (students)	4.60	4.52	Very Valid	90.40% of the criteria in the indicator are met
	b. The game application has a hint button other ways of playing/navigation that allow students to learn independently accompanied by the opportunity to choose the correct answer	4.40			
	c. Game applications use clear audio (narration, *sound effects*, or *back sounds* are heard clearly*)*	4.20			
	d. Game applications use proper visualization (*layout*, typography, and colors used in game applications are following the characteristics of junior high school students and have an attractive appearance)	5.00			
	e. Game applications use appropriate and attractive animations or illustrations for each item presented	4.40			
	f. Game applications use appropriate language (straight forward, dialogic, interactive, following student development, and using good and correct Indonesian language rules)	4.60			
Game Component Assessment Game	a. applications can trigger the growth of cognitive abilities (such as providing experience to go through the process of mastering the material and involve them in difficult situations), engages the user in a variety of emotions (curiosity, confusion, disappointment, happiness), and improve students' social attitudes (such as being able to compete in a sporting manner when playing with classmates, making failure an opportunity to study harder, and not easily give up), so that it can motivate users/students in learning to master the game and fulfill their feelings. want to know	4.80	4.80	Very Valid	96% of the criteria in the indicator are fulfilled
	b. Game applications use the concept of game mechanics, meaning that there are aesthetics and thinking games that bind players, motivate and improve the quality of learning through problem-solving.	4.60			
	c. The game application contains *a goal focus* which is to improve students' problem-solving and critical thinking abilities which can be shown through the achievement of all available levels and the achievement of the final score for each player	4.80			
	d. Using *objectives* through level division consisting of questions by category easy (level 1), confirmation of knowledge through video viewing (level 2), medium (level 3), and difficult (level 4)	4.80			
	e. These *rules*/rules in game applications, so that players are involved in the learning process with game concepts given and form a new perspective on learning	4.40			
	f. Game applications involve students actively participating (*engagement*) which is shown through *the Challenge* (the challenge of completing each level) and *rewards* (in the form of points/scores per item at each level) and the *leaderboard* (a list of the number of points/scores obtained by players)	5.00			
	g. *Challenges* are given according to the stages of student development and can improve the abilities, skills, and skills of players (students)	4.80			

	h. Through gamification, students can see failure as an opportunity to keep trying and attract student learning interest	4.80			
	i. Game applications can be used to help teachers monitor the progress of student development as one of the learning evaluation materials	5,00			
for Content Assessment Material	a. Game applications use a material that is appropriate to learning outcomes and learning objectives that students must achieve	4.80	4.76	Very Valid	95.20% of the criteria in the indicators fulfilled
	b. Game application equipped with clear and correct material substance following learning outcomes	4.60			
	c. Game applications provide useful material to broaden students' knowledge and skills	4.60			
	d. Game applications use learning materials that are appropriate and appropriate to the level of ability and student development	5.00			
	e. Material presented in in-game applications fosters motivation to learn	4.80			
	f. The order of presentation of material in-game applications is appropriate	4.80			
Video Content Assessment	a. Material content in learning videos is relevant to learning outcomes and learning objectives	4.80	4.88	Very Valid	97.60% criteria in the indicators fulfilled
	b. Stage learning in video corresponds to contextual learning.	4.80			
	c. Conformity of images and illustrations with the material presented.	5.00			
	d. Suitability of the sample with the material presented.	5.00			
	e. Ease of using videos (learning videos presented are easy to use and follow students' ability levels)	4.60			
	f. Accuracy in using language (the language used in game applications is straightforward, dialogic, interactive, following student development, and uses Indonesian language rules well and correctly)	5.00			
Overall Rating Average			4.70	Very Valid	94% of the criteria in the indicators are met

Based on the table, the assessment of the learning device aspect is 4.56. That shows 91.20% of the criteria have been met and are classified as very valid categories. The assessment of visual communication aspects obtains a rating of 4.52 which shows that 90.40% of the criteria have been met and are classified as very valid categories. The assessment of game component aspects obtained a rating of 4.80, indicating that 96% of the criteria had been met and were classified as very valid categories. The material content assessment obtained an assessment of 4.76, indicating that 95.20% of the criteria had been met and classified as a very valid category. The evaluation of the learning video content obtained a rating of 4.88, indicating that 97.60% of the criteria had been met and classified as a very valid category. Thus, the GEMAS game received a rating of 4.70, which means it has fulfilled 94% of the specified criteria and is classified as very valid.

Based on data on the validity assessment of gamification-based teaching materials in the developed GEMAS game, namely the assessment of the validity of problem-solving skills, critical thinking, and the validity of GEMAS game content, an overall average rating of $\underline{x} = \frac{4.51 + 4.70}{2} = 460$. These results indicate that 92% of the GEMAS game content validity indicators that have been developed have been fulfilled and are classified as very valid criteria so that they are suitable for use in classroom learning.

Results and Discussion

1. Analysis . The main activity in this stage is conducting a preliminary study, including field surveys and literature studies regarding needs analysis for developing gamification of teaching materials for 21st century skills of junior high school students, along with the indicators to be used. The literature study includes studying the junior high school mathematics curriculum, especially the independent curriculum in mathematics, ICT-based learning methods, and gamification in mathematics learning. Aside from that, an initial analysis of 21st century skills of junior high school students includes problem-*solving and* critical mathematical thinking.

2. *Design and Development*

After reviewing the curriculum and content, designing learning scenarios in the form of level games, and creating layouts or display designs for teaching materials, the next step is to design learning video content displayed in the *game*. This activity produced seven animated learning videos on the material of one-variable linear equations and a two-variable linear equation system. The seven videos developed for level 2 of the game. These seven videos are briefly shown in figure 3.

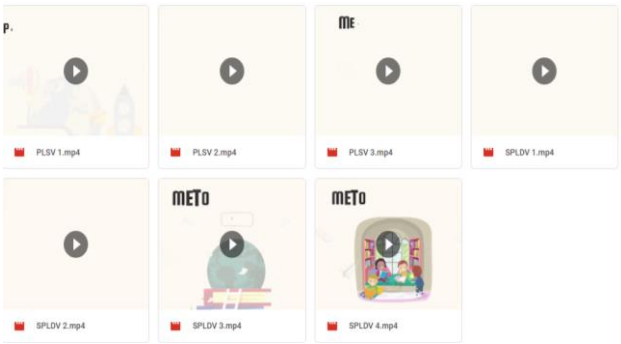

Figure 3. Animated Learning Video about PLSV and SPLDV

The next step is to develop game content as test instruments on the material of one variable linear equation and a system of two variable linear equations. The test instruments were developed for problem-solving abilities (using Krulik and Rudnick indicators) and mathematical critical thinking abilities (using FRISCO indicators). The test instruments are divided into easy, medium, and high-difficulty levels according to levels 1, 3, and 4 in the game. This test instrument was then validated by a team of experts (5 experts in Mathematics Education) which was carried out through the Delphi technique, carried out by a group of experts continuously through a questionnaire without the need for all face-to-face meetings (Lukman & Setiani, 2018) .
After the test instruments for problem-solving abilities and critical mathematical thinking are declared valid and feasible, the following research stage is to create a storyboard and develop material in the form of a game. This game is named GEMAS (Junior High School Mathematics Educational Game). In summary, the results obtained are presented in the following figure.

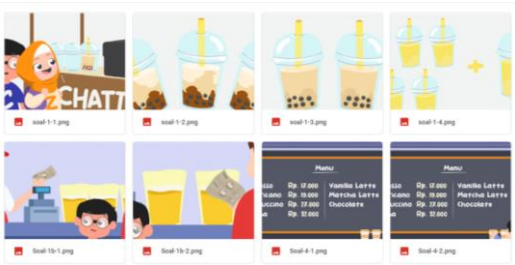

Figure 4. Illustration of the questions in the GEMAS application

Figure 5. Initial display of the GEMAS application

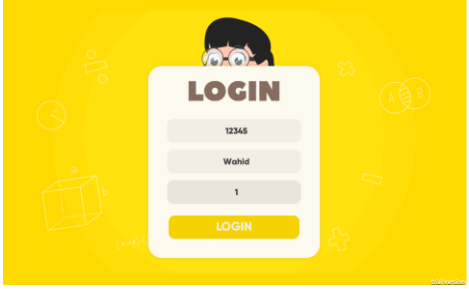

Figure 6. Display of the GEMAS Application Log in

Figure 7. GEMAS Application Main Menu

Figure 8. The Module Menu in the GEMAS Application

Figure 9. Display of the Play Rules Menu

Figure 10. Level Menu in Each Module

Figure 11. Display of Questions at each level

Figure 12. Display of Level 1 Question Items

Figure 13. Video display in Level 2

Figure 14. Video display in Level 2

The results of statistical data analysis show that the GEMAS game is suitable for use in learning. That is because the appearance of teaching materials is formed as a game requiring active student involvement. Visualizations and illustrated images can trigger student motivation in learning, directing specific skills, especially problem-solving skills, and critical thinking, and adapting to the character of junior high school students. So that experts judge that teaching materials follow the purpose of gamification, where games or moving visualizations are specifically designed to teach specific skills to students. So that the learning process motivates students to think and solve problems (Farida, 2018; Jusuf, 2016; Prambayun et al., 2016; Pujakusuma & Dkk, 2018) by prioritizing enjoyment and engagement (Lee & Hammer, 2016; Rohaila & Fariza, 2017). If student motivation has increased, it is easy to improve the competencies, skills, or abilities to be achieved. That is why the development of digital games has increased in education (Rohaila & Fariza, 2017). In addition, GEMAS games are specifically designed to improve students' mathematical critical thinking and problem-solving abilities through games. That is evident from the results of content validation by experts showing that the characteristics of the items used in the game follow the indicators of students' problem-solving abilities and critical mathematical thinking and are declared very valid. This result is in line with Cahyadi's opinion (Cahyadi, 2019) that suitable teaching materials must support the improvement of the quality of one's knowledge or be progressive.

Even though it is classified as a very valid category and suitable for use in learning, there are still several indicators with a relatively small value. Based on the results of data analysis on content feasibility assessment, an indicator that still has a relatively small value compared to other indicators is the accuracy of pictures, diagrams, and illustrations. Because several images are small in size, the writing is not readable on the GEMAS game. Likewise, in assessing the feasibility of using language, a relatively small value compared to other indicators is the accuracy of sentence structure. That is because some questions have typos and ambiguous meanings, so it is feared that students can understand the intent of the question items properly.

Furthermore, in assessing the suitability of the items with the Krulik and Rudnick problem-solving indicators, indicators of alternative solutions must be found and discussed while still getting the lowest scores among the other indicators. That is because the questions are in the form of multiple choice and short descriptions, so

they have yet to be able to facilitate students to explain alternative solutions in detail in each discussion of the questions.

Furthermore, in assessing the suitability of the items with the Critical Thinking indicator with FRISCO, the lowest score was found on the student indicator of being able to make the correct conclusions. That is also because the choice of concluding answers is already available, so students only match the appropriate conclusions. Meanwhile, the lowest score was on the indicator of the availability of clear installation instructions and instructions for using the media. That is because the game application still needs to install an exact application installation method, only there are instructions for playing at each level. Based on this assessment, the GEMAS application was revised in the completeness of the instructions for use, complete with a detailed installation guide, added an audio on-off feature, increased the duration of the audio, changed the sentence structure in each item to make it easier to understand, corrected typing errors, and added features zoom in zoom out on the application so that the image can be enlarged and reduced

Games bring to users in their early teens. The positive effects include the speed of material delivery and increased skills and focus, while the negative effects include addiction, aggressive behavior, difficulty absorbing conventional material and decreased physical activity. However, one of the game genres that has a positive effect on its users is educational games (Prasetyo, Bastian, & Sifana, 2020). And so far, no negative effects have been found from educational games that have been developed.

The GEMAS game is alongside traditional teaching materials that are widely available. That is because the resulting product is in the form of a game installed on the Google Play store so that the use process allows it to be used independently or in collaboration as a complement to traditional teaching materials. That aligns with some of the results of previous studies, which also show that educational games as learning media have several advantages and disadvantages. For example, users can use them anywhere and anytime, increasing students' interest and activeness in the learning process. Apart from the advantages, the disadvantages of educational games are that the material used in the media is limited, an explanation is needed from the teacher regarding the material before the media is used, or the content of the material does not yet explore higher-order thinking skills (Karlina & Abidin, 2022). It could be if this game is juxtaposed with traditional teaching materials to minimize shortcomings.

The research limitations in the first year were the new research stages up to the development of 2D games and content validation by a team of experts. However, trials were not conducted on actual users, namely junior high school students. Therefore, it is necessary to conduct trials in the environment to see the positive and negative effects of the games being developed, their practicality, and their effects on students' problem-solving abilities and critical thinking. This follow-up research will take place in 2023 and will be carried out in three junior high schools in Sukabumi town involving around 150 students. In addition, the material used in this study is also limited to a system of two-variable linear equations, so in future studies, other materials will be added, including geometry and statistics.

Conclusion

Based on the analysis of content validity data related to the GEMAS game that has been developed, it is found that the criteria in the context of problem-solving abilities and critical thinking skills used are 90.20% fulfilled, and the fulfilment of game content criteria reaches 94%. These data show that 92% of the GEMAS game feasibility assessment criteria have been met. Thus, the gamification-based teaching material in the form of the GEMAS game has been developed as an assessment in a very valid category and is suitable for use in learning.

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