How to Determine The Quality of Game-Based Media for Mathematics Learning?

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Abstract
Development research has become one of the popular studies in the 5.0 society era. Technological sophistication is a driving factor for educators and researchers to create sophisticated learning media. Technology-based learning media comes with their own uniqueness, one of which is game-based media (GBM). GBM has changed students' perception that learning can be done by playing games. Before GBM is applied in the learning process, it is necessary to evaluate the media. This is intended so that GBM has good quality. GBM with high quality can improve its functions as a learning medium. On the other hand, GBM can not only present an element of fun learning, but can also have a positive influence on the cognitive, affective, or psychomotor aspects of students. This literature review research provides theory for educators and other researchers to assess GBM. Overall, there are four aspects that need to be assessed in determining quality of game-based media: validity, practicality, effectiveness, and sophistication.

Keywords: mathematics learning; game-based media; quality of game; aspects of media assessment

Abstrak
Riset pembangunan menjadi salah satu kajian yang populer di era masyarakat 5.0. Kecanggihan teknologi menjadi faktor pendorong bagi para pendidik dan peneliti untuk menciptakan media pembelajaran yang canggih. Media pembelajaran berbasis teknologi hadir dengan keunikan tersendiri, salah satunya adalah media berbasis *game* (GBM). GBM telah mengubah persepsi siswa bahwa belajar dapat dilakukan dengan bermain game. Sebelum GBM diterapkan dalam proses pembelajaran, perlu dilakukan evaluasi media. Hal ini dimaksudkan agar GBM memiliki kualitas yang baik. GBM dengan kualitas tinggi dapat meningkatkan fungsinya sebagai media pembelajaran. Di sisi lain, GBM tidak hanya dapat menghadirkan unsur pembelajaran yang menyenangkan, tetapi juga dapat memberikan pengaruh positif terhadap aspek kognitif, afektif, atau psikomotor siswa. Penelitian tinjauan pustaka ini memberikan teori bagi pendidik dan peneliti lain untuk menilai GBM. Secara keseluruhan, ada empat aspek yang perlu dinilai dalam menentukan kualitas media berbasis game, validitas, kepraktisan, efektivitas, dan kecanggihan.

Kata Kunci: pembelajaran matematika; media berbasis permainan; kualitas permainan; aspek penilaian media

1. INTRODUCTION

Learning media is an important tool that currently cannot be ignored in the learning process. This is because learning media has an important role in regulating learning activities (Tafonao & Setinawati, 2019). In addition, learning media also has an influence on student learning outcomes (Yuliansih, Arafat & Wahidy, 2021). The existence of teacher learning media facilitates the transfer of knowledge and class activities feel more real. Learning media also makes learning interactions that occur no longer one-way but can be designed to be multi-directional.

Several studies have shown some of the benefits of learning media in the learning process. Learning media increases motivation, interest, curiosity, self-confidence and other affective aspects (Yuliansih, Arafat & Wahidy, 2021). Learning media is also able to improve understanding of concepts, problem solving to higher order thinking skills (Ardani & Salsabila, 2020). The benefits are no doubt that learning media has an important role in the learning process.

For decades, mathematics at the primary and secondary school levels. considered as a difficult and boring subject (Ardani, Handican, Salsabila & Setyaningrum, 2018). Even though the teacher has presented learning media in the learning process in the classroom, the paradigm is still the same. Abstract mathematics is difficult and students like to learn to memorize formulas that are not applied in their lives (Ardani, Handican, Salsabila, & Setyaningrum, 2018).

The presence of technological sophistication has slowly changed the paradigm. One way that has been done by teachers is to present technology-based learning media (Umoh, Sheik, Isong, 2021). The learning process is no longer done by explaining the material but students can be directly involved through more enjoyable learning activities by using these learning media.

The higher the current technological sophistication, the development of technology-based learning media is also increasingly massive. Several recent studies have shown that the development of technology-based mathematics learning media is one of the top topics, especially game-based learning media which in this paper is referred to as GBM. For example, research on the development of GBM as a medium for learning mathematics is shown by the following research (Tokac, 2021; Pratama, 2018; Dewantara, 2022).

Although GBM has very high usefulness, it is necessary to pay attention to the quality of the GBM. The quality of GBM certainly has a high influence on student learning outcomes (Ariffin, Oxley & Sulaiman, 2014) In addition, the quality of GBM used will affect the learning process. Therefore, in this case the quality of GBM is highly emphasized.

Based on the results of the literacy study, there were several GBM development studies that failed or did not match the initial goals. As an example, (Anderson, 2018; Yang, 2020).

The failure to develop GBM is broadly divided into two problems. First, the GBM implementation process is constrained. The availability of technology, students' skills in using media and time constraints make the process of using it done in a hurry (Anderson, 2018; Yang, 2020). Second, because the quality of GBM is not optimal, one if them is due to incomplete learning game design elements (knowledge, incentive system, learning mechanics, assessment mechanics, aesthetic design, narrative, musical score) (Plass, 2015).

Before GBM is used in the learning process, GBM developers need to know the quality of the GBM. The quality of GBM can be seen from the assessment process carried out (Ifenthaler, Eseryel, & Ge, 2012). To carry out an assessment of GBM, the developer needs a good and complete assessment instrument. A good and complete assessment instrument certainly affects the level of confidence in the quality of the object being assessed (Ifenthaler, Eseryel, & Ge, 2012).

The GBM assessment instrument has two very useful benefits for a developer. First, the instrument can be used as a guide in developing good GBM. Developers can consider certain things based on the minimum requirements of the instrument. Second, the instrument used to assess the quality of GBM before GBM is fully utilized. assessment, developers can see the quality of GBM and find out what things still need to be improved through.

This literature review research focuses on how a researcher really knows the quality of the GBM that has been developed. Therefore, developers need an appropriate instrument to determine the quality of GBM. This need will be answered through this literature review research by presenting an instrument to assess learning media, especially GBM. To solve the problems that arise in this study, the research questions are described as follows: "What is the right form of the "GBM" game-based mathematics learning media quality assessment instrument?

1.1 Character of Mathematics Learning

Mathematics is a branch of exact science with abstract characteristics. Mathematics is taught in formal schools from elementary to high level. According to the National Council of Teachers of Mathematics (NCTM) there are five branches of mathematics that need to be mastered by students in learning mathematics at school, including number sense, properties, and operations; geometry and spatial sense; algebra and functions; measurements; and data analysis, statistics, and probability (NCTM, 1998).

School mathematics refers to the mathematical abilities that students must possess to solve real problems in their lives. According to the National Assessment of Educational Progress (NAEP) there are two mathematical abilities, mathematics abilities and mathematical power (NCTA, 1996). Mathematical abilities relate to the knowledge or

processes involved in completing a task well. Mathematical abilities are divided into three abilities, conceptual understanding, procedural knowledge, and problem solving. The second ability is mathematical power which consists of mathematical ability to do reasoning, connections, and communication.

Based on the characteristics and content of mathematics as well as the mathematical abilities that students need to achieve, there are several things that become the basis for implementing mathematics learning in schools. Teachers need to recognize that all students can develop positively and become strong mathematics learners; responsive to the diversity of cultures, thought processes and realities found in everyday classrooms; optimizing various academic outcomes which include conceptual understanding, procedural fluency, strategic competence and adaptive reasoning; and is committed to improving social interaction in math class (Anthony & Walshaw, 2009).

Mathematics learning in schools also pays attention to how mathematical concepts and principles can be conveyed properly to students. According to Kiwakuna, et al., there are three aspects that need to be considered so that mathematical knowledge can be conveyed properly to students (Kiwakuna, et al., 2016).

1) bring self-confidence to students;
2) presenting the relationship between mathematics and its application so that students realize the usefulness of mathematics in real life; and
3) presenting fun learning activities.

One way that teachers can do in fulfilling the foundation of learning mathematics is to prepare learning tools and media. Teachers need to prepare effective learning media to support and expand mathematical reasoning (Anthony, & Walshaw, 2009). The same thing was also expressed by Blanton & Kaput said that teachers have an important role to ensure that the learning media used are effective in supporting students to have mathematical understanding and reasoning (Blanton & Kaput, 2005). Learning media is very helpful in communicating mathematical concepts that are difficult to convey. Through the media, teachers and students can represent mathematical knowledge in the form of stories, pictures, symbols, concrete objects, virtual manipulatives (Blanton & Kaput, 2005).

1.2 Game-based Media
Along with the development of time, the variety of learning media is increasing. This is part of the teacher's efforts to try to fix the interest and motivation of students to be involved in learning mathematics. The majority of existing learning media are already integrated with technology such as e-books, interactive multimedia, video explanations, web-based conferencing, android-based apps and others.

Learning media that is currently in demand by media developers is game-based learning media (GBM). It is concluded from the following facts. First, the majority of mathematics learning media available on the Google Play Store are game applications. Second, from a survey conducted by the author on 27 respondents who carried out the development of learning media, 19 respondents developed digital learning media and 8 developed non-digital learning media. Furthermore, of the 19 respondents who developed digital learning media, 12 developed GBM and 7 others were not related to GBM. Based on these conditions, it can be said that GBM is currently a research trend in the development of mathematics learning media.

GBM is one type of learning media in the form of video games that contain content related to games and teaching materials (Ge & Ifenthaler, 2018) Therefore, GBM as a medium for learning mathematics contains game content and math material. Basically the concept of GBM itself is a video game that involves electronic devices in its use (Ge & Ifenthaler, 2018). GBM here is not a learning design that presents training or performance in the form of games.

Several studies have shown that learning with GBM is something that is most rapidly growing in learning in schools. GBM can be applied as a medium in the form of web-based games, virtual games, simulation games, online games, Android-based games and games with multiple users. Through several interesting activities and students are given the opportunity to make decisions, GBM has a positive influence on the affective and cognitive aspects of students (Tokac, 2021; Pratama, 2018).

1.3 Quality of Game-based Media

Organized GBM certainly provides many benefits for both teachers and students, improving affective and cognitive as well as more modern time and learning methods for students. Based on its characteristics, GBM has a higher chance of generating interest in learning in students. Seeing good opportunities in GBM, therefore special attention needs to be paid to the GBM development process.

Although the research that has been done shows the benefits of GBM, there are things that still need to be improved. Based on the results of Ardani's research, prospective mathematics teachers have higher motivation than mathematics teachers (Ardani & Setyaningrum, 2022). Furthermore, the authors tried to conduct a survey of 18 prospective mathematics teachers who were developing GBM, and 18 prospective mathematics teachers 60% focused on the development process, 30% focused on implementing GBM in the classroom and 10% related to the feasibility test of GBM. This fact shows that the stage of paying attention to the quality of the GBM developed is still very minimal. Of the 18 prospective mathematics teachers, 17 did not have a specific reference or theory used to assess the quality of the GBM that had been developed.

Therefore, the author tries to develop a GBM assessment instrument from several literature studies that have been carried out.

The GBM assessment instrument was developed based on several principles and characteristics that must exist in GBM as a medium for learning mathematics. Mayer describes four principles in game-based learning media; (1) have a target of achieving a competency that will be possessed by students; (2) presents a variety of challenges that do not stop motivation and interest; (3) according to the characteristics of students; and (4) in accordance with the learning activities in the class (Mayer, 2016). GBM which contains these principles certainly makes the learning objectives clearer and more focused. When the developer ignores this principle, of course the GBM developed is only focused on the pleasure aspect that will be felt by the user. Again, GBM here is not an entertainment game but as an alternative medium for learning mathematics.

In developing GBM, there are aspects that need to be considered by developers. As a medium for learning mathematics, GBM needs to pay attention to (1) the objectives of the game; (2) subject discipline; (3) the genre of the game; (4) platform or game delivery method (Connolly, 2012). Next, Norman, describes six aspects related to the abilities of students that need to be considered in developing GBM, (1) paying attention to the user's perceptual-motor abilities; (2) cognitive-verbal balance; (3) presenting problems, (4) information utilization; (5) persistence; and (6) consider human interaction (Norman, 2011). Indicators of the ability of students in the aspects presented by Norman can be seen in detail in Table 1.

Table 1. Indicators on aspects of GBM

Aspect	Indicator
Perceptual-motor	perceptual speed, pattern recognition, object identification, simple and choice reaction time, tracking, targeting, timing, rhythm, and response mapping
Cognitive-verbal	processing or interpreting information
Problem solving	ability solving problematic, ability assessing and using probabilities in a game
Information-utilization	using information from memory about events, names, and places in a game and also filtering out irrelevant information
Persistence	having the patience to continue through difficult or boring parts of the game
Interaction	competing and communicating with other players

2. METHOD

The purpose of this study was to develop a Game-based media assessment instrument as a medium for learning mathematics. Furthermore, the authors conducted a literature review to obtain a theoretical basis for the development of GBM assessment instruments. The literature sources are based on theories that support and relate to the development

of GBM. In addition, the author also refers to several research results related to the use of GBM in the mathematics learning process. So far, we have reviewed.

The quality of the instrument becomes a very important thing in assessing the quality of a media. If the media that is judged to have met the requirements, the success rate in achieving the goal of using the media will be much higher. In addition, the quality or quality of the media used will have a high influence on the output of the user. The GBM assessment instrument is based on two important points. First, the instrument was developed based on theories related to learning media, game-based learning media, IT-based media, and interactive multimedia. Second, the instrument also considers the content of the material contained in GBM, especially mathematics material. The GBM assessment instrument in this study was developed to assess 4 things; (1) assessing the suitability of GBM with the intended use; (2) assessing the usefulness of GBM as a medium for learning mathematics; (3) assessing the function of GBM in improving cognitive and affective and; (4) assessing the technology used in GBM. The literature review research procedure that has been carried out by the author can be seen in Figure 1.
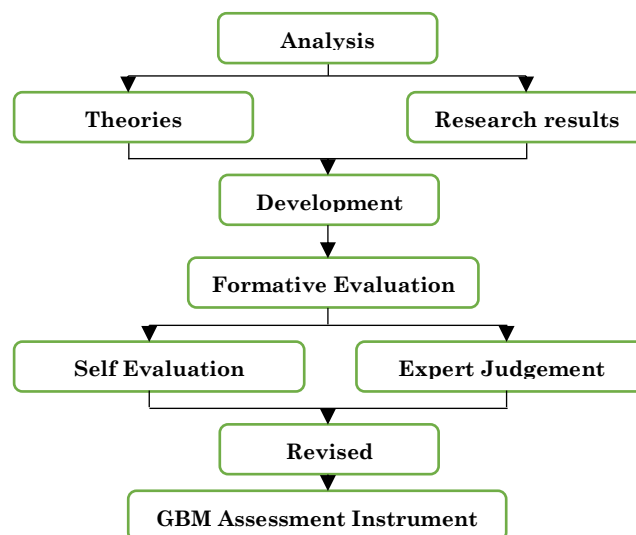
Figure 1. Research procedure

This literature review research starts from the activities of analyzing theory and research results related to the development of GBM. After the analysis is done, the authors present the results in the form of a GBM assessment instrument. Before the instrument was disseminated, the instrument was evaluated in a formative, independent evaluation and expert judgment. The results of the evaluation become the basis for the author to determine which parts of the instrument need to be improved, changed, or deleted. GBM assessment instruments that are already suitable can be used by GBM developers, especially in the field of mathematics.

3. RESULTS AND DISCUSSION

The quality of the assessment instrument is the basis for how the quality of an object or subject is assessed. When the assessment instrument has good quality or validity for what will be measured, it can be ascertained that the results of the assessment have a high level of accuracy. Therefore, a GBM quality assessment instrument is needed so that the quality of GBM developed reaches optimal quality. The GBM assessment instrument was developed based on the following reviews.

Basically the criteria for a good learning media are media that meet the criteria of validity. The validity of a media is related to the level of accuracy of the material and content presented on the media (den Akker, 1999). Aspects of validity can be seen from two aspects, namely content and construct (den Akker, 1999). Nieveen explained that content validity assesses how knowledge is presented by taking into account the state of the art knowledge (Nieveen, 1999). Meanwhile, Walker & Hess describes content validity which examines aspects of material accuracy, importance, completeness, balance, attracts interest/attention, suitability to student conditions, quality of tests and assessments, and has an impact on students and teachers (Arsyad, 2011). Based on this review and the principles on GBM conveyed by Norman, the authors conclude that there are seven indicators in assessing the validity of GBM content, (1) completeness of material; (2) breadth of material; (3) depth of material; (4) material integration; (5) accuracy of concepts and definitions; (6) accuracy of examples and cases; and (7) description of material substance presented in proportion of learning goals.

In addition to content validity, construct validity also needs to be taken into account in assessing the quality of a media. Construct validity examines how the quality of the technique of delivering material and other content is presented in the media. Walker & Hess reviewed construct validity from aspects (1) reliability; (2) easy to use; (3) display quality; (4) quality of feedback; and (5) the quality of program management (Arsyad, 2011). In addition, construct validity is also related to the components in the media that are interrelated with one another. The assessment of construct validity in GBM reviews four aspects including (1) suitability of illustrations with material; (2) writing of mathematical symbols; (3) availability of apperception; (4) availability of evaluation; and (5) material delivery techniques.

After the media is judged to be valid, the next step is to determine the practicality criteria that also need to be measured to see the quality of a media. Practicality refers to how the media that has been developed can be used easily and has enormous uses. This also applies to the practicality of using GBM later. According to Fraenkel & Wallen, the practicality of GBM can be viewed from 5 aspects, (1) ease of use; (2) time required; (3) ease of scoring; (4) costs; and (5) problem presentation technique (Fraenkel & Wallen, 1993). In addition, Valcke revealed that "usefulness and ease of use are indeed key determinants to predict mobile game usage and acceptance" (Bourgonjon, 2010). The same

thing was conveyed by Nieveen that the practicality of a GBM can be seen from the aspect of the usefulness of GBM as a medium in transferring knowledge and the ease of operation of the media by users (Nieveen, 1999). Furthermore, the authors conclude that the practicality of GBM can be assessed from two main aspects, namely usefulness and ease of use. Then the author tries to describe the two aspects based on the following assessment indicators. The usefulness aspect has six assessment indicators, (1) enhancing cognitive; (2) enhancing affective; (3) psychomotor enhancing; (4) facilitating independent or group learning; (5) motivating students; (6) time used. The ease of use aspect can be reviewed based on three indicators, (1) difficulty level; (2) flexibility of use; and (3) acceptable materials.

The third criterion in the GBM assessment is how effective the GBM is. Effectiveness can be expressed as a form of success about the effort or action (Bourgonjon, Valcke, Soetaert & Schellens, 2010). To achieve effectiveness in the use of GBM, the authors referred to four levels of effectiveness based on Kilpatrick (Bourgonjon, Valcke, Soetaert & Schellens, 2010). The first level is assessing reaction and attitude. The first level measures how students react and behave when using GBM as a medium for learning mathematics. In general, at this level the developer can see the interest, motivation, interest, and confidence of students in learning mathematics. The next level is assessing learning. This second level refers to how the implementation of learning is based on student outcomes such as the achievement of an ability and skill. The third level is assessing behavior change in the intended environment. The third level is aimed at knowing the changes in point of view and attitudes significantly after students use GBM. The difference between the first level and the third level is that the first level assesses the attitudes that arise while the third level is more focused on changing the final attitude with the students' initial attitude. The last level is assessing results ad return on investment.

GBM is a learning medium that involves technology both in its development and application. Due to the use of technology, it is necessary to assess how advanced the technology is in GBM. Technology that is not well organized will certainly cause problems in its use. Because the key to the success of technology-based media such as GBM is also based on how the technology is integrated well. To assess the GBM sophistication criteria, the authors adopted the mobile learning assessment by LORI (Kilpatrick & Swafford, 2011). Sophistication assessment criteria consist of eight aspects, (1) content quality which assesses simplicity, precision, balanced idea and the level of difficulty in each level; (2) learning goal alignment related to the alignment between learning objectives and material, and student characteristics; (3) feedback (assessment and feedback for students); (4) affective assessing the ability of the media to motivate and make students interested in using it; (5) the percentage design assesses several indicators such as, visual media and audio information design accommodation to enhance learning and learning efficiency, ease of navigation, user predictability, interface quality and presence of media usage instructions; (6) accessibility includes control design and format of material

delivery; (7) usability of the media to be used in various learning contexts and with students from various backgrounds; and (8) standards compliance as medium.

Overall, there are four criteria to assess GBM as a medium for learning mathematics, its validity, effectiveness, practicality and sophistication. The four criteria are further elaborated by the author into several assessment indicators. Although this assessment instrument has not been tested directly, it has been validated by evaluation experts, mathematicians and technologists. Based on the final validation results, the GBM assessment instrument has high validity even though it initially went through several stages of revision.

4. CONCLUSION

The final form of the GBM assessment instrument as a medium for learning mathematics can be seen in Table 2.

Table 2. Game-based media assessment criteria and indicators

Criteria	Aspect	Indicator
Validity	Content	Completeness of material, breadth of material, depth of material, material integration, accuracy of concepts and definitions, accuracy of examples and cases, description of material substance presented in proportion to learning goals
	Construct	Suitability of illustrations with material, writing of mathematical symbols, availability of evaluation, material delivery techniques
Practicality	Usefulness	Enhancing cognitive, enhancing affective, enhancing psychomotor, facilitating independent or group learning, motivating student, time used
	Ease of Use	Difficulty level, flexibility of use, acceptable material
Effectiveness		Reaction and attitude
		Cognitive ability
		Behavior change in the intended environment
		Result and return on investment
Sophistication	Content Quality	Simplicity, precision, balanced idea and the level of difficulty in each level
	Learning Goal Alignment	Alignment between learning objectives and material, and student characteristics
	Feedback	Assessment and feedback for students
	Affective	The ability of the media to motivate and make students interested in using it
	Presentation design	Visual media and audio information design accompaniment to enhance learning and learning efficiency
	Accessibility	Includes control design and format material delivery
	Usability	The ability of the media to be used in various learning contexts and with students from various backgrounds
	Standards compliance	Standard adjustment as medium

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