

## **DEVELOPMENT OF A GAME-BASED ASSESSMENT APPLICATION ON THE CONCEPT OF MOMENTUM AND IMPULSE (GAMBAS MIE)**

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**Abstract.** Misinterpretation of questions is one of the causes of low student learning outcomes. This study aims to address this issue by developing a Game-Based Assessment application on the subject of momentum and impulse, which includes illustrations and animations for each concept explanation and question. This study uses the 4D method (Define, Design, Development, and Disseminate). The 4D development model includes four stages: (1) Define - literature study, curriculum analysis, and student concept analysis; (2) Design - creation of the game application storyboard; (3) Development - development of the game-based assessment application followed by expert validation and limited trials, with data analyzed using qualitative and quantitative descriptive techniques; and (4) Disseminate - widespread distribution of the game-based assessment application in the form of copyright. The developed game-based assessment received positive responses from students, with an N-Gain value reaching 0.86 in the high category, indicating that the game-based assessment can improve students' conceptual mastery on the topic of momentum and impulse.

**Keywords:** game-based assessment, learning outcomes, momentum and impulse

### **INTRODUCTION**

The learning process and assessment are inseparable. Assessment shows the results of the learning process provided by teachers. Through assessment, teachers can understand students' conceptual mastery of the taught material (Guangul et al., 2020; Archer, 2017). Research by Sari et al. (2018) at senior high school level showed that the average test scores of students in physics were still below the Minimum Competency Criteria. One of the reasons students often score low is their misunderstanding of the given questions. Physics assessments often involve long sentences to describe an event, leading to students misinterpreting the questions (Charli et al., 2018). Additionally, assessments in schools are still paper-based, and questions describing events are written in long sentences, causing students to misread the questions (Alifiyah et al., 2021). To address this problem, some researchers have found that digital-based assessments can display questions in the form of images and animations, one of which is game-based assessment (GAMBAS) (DiCerbo, 2020; Putri et al., 2020; Shute et al., 2017).

GAMBAS positively impacts education as it helps students complete their homework effectively and makes them more enthusiastic and confident in solving problems that usually require explanation. However, research supporting GAMBAS is somewhat limited in physics concepts, indicating that GAMBAS needs further development (Shute et al., 2013; Delgado et al., 2016; Alifiyah et al., 2021). In the

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digital era, student dissatisfaction with educational media is increasing, especially with educational video games (Lestari et al., 2020). Besides being entertainment, games can be played in real life (Amany & Desire, 2020). Currently, GAMBAS is being implemented in various fields, including education. Assessment and games can enhance learning and provide interactive learning experiences to students (Demir, 2020).

One game model that can be used as GAMBAS is a board game. Board games are chosen because they effectively deliver material and learning in and out of the classroom. Additionally, board games impact students' mastery and learning outcomes (Prihandoko & Yunianta, 2021). This study focuses on developing GAMBAS using a board game model on the topic of momentum and impulse, called GAMBAS MIE (Game-Based Assessment Momentum and Impulse). An engine is needed to create GAMBAS MIE, and the chosen engine is Adobe Animate CC. Adobe Animate CC is used because it is easy for educators to learn and use in game development. Adobe Animate CC also supports programming languages like ActionScript, audio, and video in application development. Therefore, the GAMBAS MIE application is expected to strengthen students' independent learning, complemented by material content before conducting assessments.

#### RESEARCH METHOD

The research method used in this study is the Research and Development (R&D) approach. This study aims to design and develop a GAMBAS on the topic of momentum and impulse through the GAMBAS MIE application, which includes illustrations and animations in each question. The implementation of this R&D research is formulated into four development stages or the 4-D cycle model. The 4-D development model consists of Define, Design, Development, and Disseminate (Zahroh & Sudira, 2014). Figure 1 shows description of the development stages involved in this research.



**Figure 1. Steps of the 4D development model**

In the define stage, two analyses were conducted: curriculum analysis and concept analysis. First, curriculum analysis was performed to examine the competency demands stated in the Core Competencies and Basic Competencies. Second, concept mastery analysis was based on observations and test scores to assess the extent of students' mastery of the curriculum demands with the aim of determining the content and material on momentum and impulse required through the development of the GAMBAS MIE application to achieve students' curriculum attainment.

The design stage began with the creation of a storyboard for the game-based assessment to be developed, based on the previously determined content and material. The storyboard was created using Microsoft Word by utilizing the shape function. This storyboard is instrumental in realizing the application. The next step involved outlining the concept and game mechanics to be used, such as determining characters, storyline, animation, and game rules.

In the development stage, the storyboard, concept, and game mechanics were realized into design and coding using the Adobe Animate CC engine. The final output

was published in several formats, such as (.apk) for Android smartphone users, (.exe) for computer program users, and (.swf) for users with Flash Player. The published GAMBAS MIE application was then validated through several stages, including expert validation (expert judgment) and limited trial (expert appraisal). The validation stage involved media experts to review navigation functions, media quality, language, and user experience of the GAMBAS MIE application. Material experts evaluate whether the long sentences transformed into animations have become effective and efficient, and assess the alignment of objectives, material, and questions. After the GAMBAS MIE application was deemed valid by the experts and revised based on their suggestions, it was then tested on a limited scale with students to assess improvements in concept mastery. The product testing followed a design that included data types, data collection instruments, and data analysis techniques. The product testing follows these steps:

### Data Type

The data used consisted of qualitative and quantitative data. Qualitative data included comments and suggestions from validators used to improve the developed instruments. Quantitative data included the average scores from questionnaires to gauge students' perceptions of the developed instruments.

### Data Collection Instruments

The data collection instruments included questionnaires and tests of students' physics concept mastery. The questionnaires in this study used a Likert scale measurement comprising three assessment aspects: content, learning interest, and display attractiveness. The instrument for testing students' physics concept mastery through the GAMBAS MIE application consisted of multiple-choice questions at the cognitive domain levels C1-C4 of the revised Bloom's taxonomy.

### Data Analysis Techniques

The data collected through questionnaires and the concept mastery test instrument on the GAMBAS MIE application given to students were then analyzed using percentages. The students' perception data obtained from the questionnaires was be analyzed using the formula below.

$$\text{Results} = \frac{\text{Obtained total score}}{\text{maximum score}} \times 100\%$$

(Ernawati, 2017)

Eligibility categories based on the criteria are shown in Table 1.

**Table 1. Media feasibility criteria**

| No | Percentage   | Criteria          |
|----|--------------|-------------------|
| 1  | < 21%        | Very not feasible |
| 2  | 21 % – 40 %  | Not feasible      |
| 3  | 41 % – 60 %  | Fairly feasible   |
| 4  | 61 % – 80 %  | Feasible          |
| 5  | 81 % – 100 % | Very feasible     |

(Ernawati, 2017)

Data on students' concept mastery are analyzed using quantitative descriptive methods. The analysis results are then described using qualitative descriptive methods to provide statements that describe the quality of the scores. To

determine the influence of the instrument on students' concept mastery, inferential statistical analysis is performed using the N-Gain Score, calculated as follows:

$$\langle g \rangle = \frac{S_{\text{post}} - S_{\text{pre}}}{S_{\text{maks}} - S_{\text{pre}}}$$

Information:

S post : Average post-test score

S pre : Average pre-test score

S max : Maximum score

(Hake, 1998)

The results of the N-Gain calculation are categorized into three levels: high, medium, and low (Hake, 1998). These categories are shown in Table 2.

**Table 2. N-Gain category**

| N-Gain Value                       | Improvement Criteria |
|------------------------------------|----------------------|
| $\langle g \rangle \geq 0,7$       | High                 |
| $0,7 > \langle g \rangle \geq 0,3$ | Moderate             |
| $\langle g \rangle < 0,3$          | Low                  |

(Hake, 1998)

The dissemination stage involves registering the copyright for the GAMBAS MIE application. The product will then be publicly distributed as an Android-based application for use in high school physics education as a learning medium.

## RESEARCH RESULTS AND DISCUSSION

In the define stage, the authors conducted several activities, including a literature study to gather information on the use of assessment types in classroom learning. The results showed that GAMBAS is rarely used in learning. Further, a curriculum analysis was conducted on the topic of momentum and impulse. The results of this analysis indicated that the momentum and impulse material is targeted at Grade X with Basic Competency (KD) 3.10, which involves applying the concepts of momentum, impulse, and the law of conservation of momentum in daily life. This curriculum analysis completes one of the steps in the define stage. The final step in this stage was analyzing students' concept mastery regarding the depth of the momentum and impulse material used to understand the extent of students' concept mastery relative to the curriculum demands. Observations and test scores indicated that students often struggle with solving problems related to the application of impulse and momentum, as well as the law of conservation of momentum.

In the design phase, a storyboard for GAMBAS MIE was created to facilitate the design process. The game mechanism used is a type of board game with dice determining the progress of the game, similar to snakes and ladders but without the snakes and ladders. Players take turns and are presented with questions before rolling the dice. In GAMBAS MIE, players who correctly answer the questions are given the opportunity to roll the dice and move according to the number rolled. Conversely, players who do not answer the questions correctly do not get to roll the dice, and the turn passes to the next player. Players who answer the questions correctly will earn a score of +10 points, while those who do not will earn +0 points. The first player to

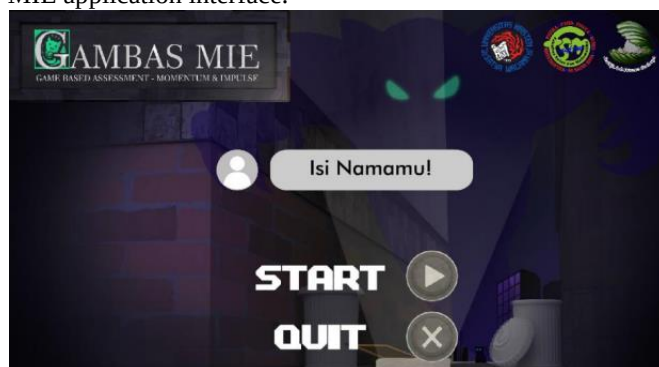
reach the finish line is the winner. However, players' understanding of the momentum and impulse concepts can also be assessed based on the leaderboard at the end of the game.

In the development phase, the previously designed storyboard was realized. The GAMBAS MIE interface created was then validated by expert validators, including media and material experts. The validator's suggestions are shown in Table 3.

**Table 3. Validator suggestions**

| Validator                         | Suggestions                                                                                                                                                                                                                                                  |
|-----------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Media                             | 1. The animation for enhancing concept understanding needs to be strengthened.                                                                                                                                                                               |
| Material and Assessment Questions | 1. Feedback is not yet available.<br>2. Adjust the size of the velocity vector arrows to match their values.<br>3. Change the font for the impulse equation. Include examples of the law of conservation of momentum for inelastic collisions in the future. |

The validation results and suggestions from the expert validators were addressed and the application was revised accordingly. Below are the results of the GAMBAS MIE application interface.



**Figure 2. Initial screen**

The initial screen of the GAMBAS MIE application consists of "start" and "quit" options.



**Figure 3. Menu screen**

The menu screen of the GAMBAS MIE application consists of "introduction," "material," and "games" content.

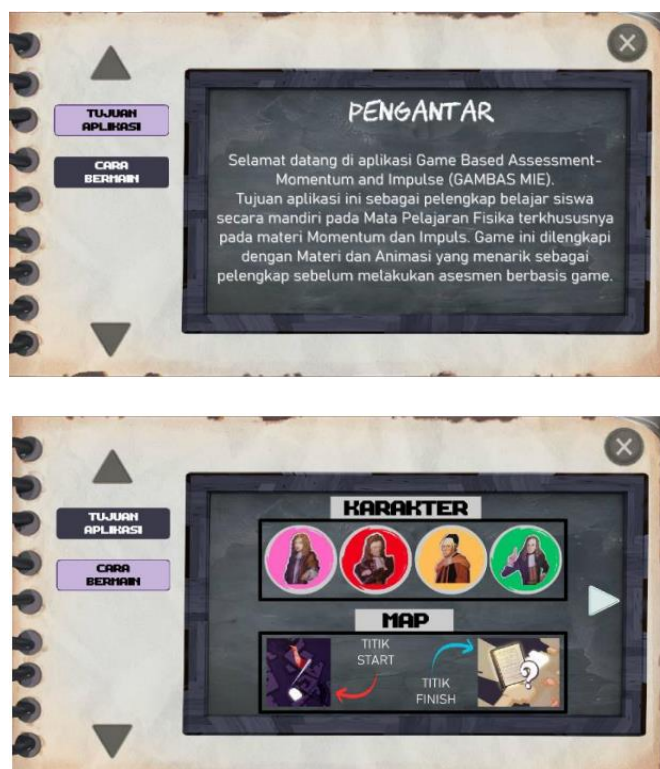


Figure 4. Introduction screen

The introduction screen of the GAMBAS MIE application consists of "application objectives" and "how to play" content.





Figure 5. Display of players, characters, and player names

The material screen of the GAMBAS MIE application consists of content on "momentum," "law of conservation of momentum," "impulse," and "the relationship between impulse and momentum." On the player selection screen, 1 to 4 players can determine the number of players, choose characters, and name the selected characters.

In the gameplay screen, players navigate a map with a white path leading to the finish line, where they find a book. The leaderboard screen appears when a player reaches the finish line.



Figure 6. Gameplay and winner screen

The question discussion screen displays each question answered by the user, providing feedback on any incorrect answers.



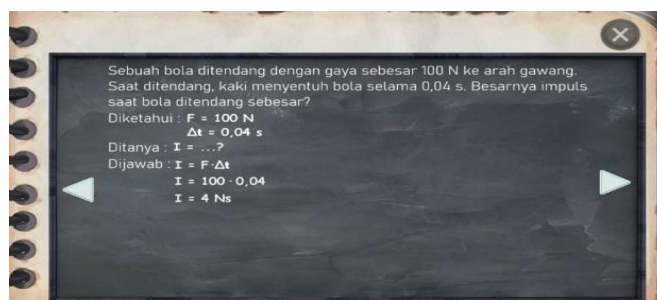


Figure 7. Question discussion screen

After the GAMBAS MIE application was validated by the material and media experts, data collection was conducted to assess the level of students' concept mastery through questionnaires and concept mastery test instruments within the GAMBAS MIE application. The trial results showed that the developed assessment application received positive responses from students. This is indicated by an average percentage score of 87% (Very Feasible), with detailed scores for each assessment aspect provided in Table 4.

Table 4. Student perception scores on the developed instrument

| Aspect               | Presentation (%) | Category      |
|----------------------|------------------|---------------|
| Content              | 81               | Very Feasible |
| Interest in Learning | 89               | Very Feasible |
| Appearance           | 92               | Very Feasible |
| Average              | 87               | Feasible      |

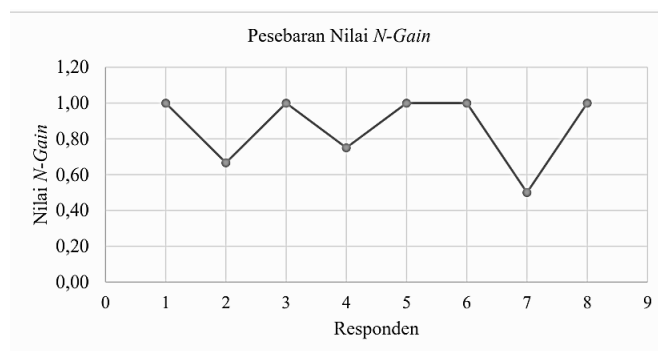
Meanwhile, the results of the pretest and posttest of students' physics concept mastery using the GAMBAS MIE application also showed improvement. This is indicated by the N-Gain value, which falls into the high category, as detailed in Table 5. This means that the developed GAMBAS MIE has a positive impact on students' mastery of physics concepts. The detailed results of the students' concept mastery tests are shown in Table 5.

Table 5. Concept mastery test results

| Test          | Pretest | Posttest | N-Gain |
|---------------|---------|----------|--------|
| N             | 8       | 8        |        |
| Mean          | 55,89   | 91,32    | 0,86   |
| Maximum Score | 90      | 100      |        |
| Minimum Score | 20      | 66,67    |        |

Based on Table 5, the average pretest score is 55.89, while the average posttest score is 91.32, and the N-Gain score is 0.86, which is in the high category. The N-Gain score indicates an improvement in concept mastery among students, with the N-Gain distribution shown in Figure 8.





**Figure 8. N-Gain value distribution diagram**

The descriptions above indicate that the use of GAMBAS MIE as a learning medium is feasible, as it effectively improves students' concept mastery. This finding aligns with previous research on mobile-based media that trains skills and is deemed valid, effective, and efficient (Nandyansah & Suprpto, 2019). It is also consistent with research by Prihandoko & Yuniarta (2021), which found that board game media is practical and effective for learning and boosts student motivation. Other researchers, like Alifiyah *et al.* (2021), demonstrated that game-based educational assessments help teachers optimally and effectively assess students, making them more engaged with the material. Similarly, research by Agustini & Pramita (2016) on the development of a snakes and ladders game for Grade 10 students showed an improvement in concept mastery, with an N-Gain score of  $\geq 0.7$  in the high category.

In the dissemination phase, the GAMBAS MIE application was registered for copyright with registration number 00048962. It is hoped that this application can be used publicly by students in large classes to help them understand problems related to impulse and momentum concepts.

## CONCLUSION

The GAMBAS MIE application developed in this research meets validity requirements, making it suitable as a learning medium. Students' mastery of momentum and impulse concepts improved before and after using the developed GAMBAS MIE application, as indicated by an N-Gain score of 0.86, which falls into the high category.

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