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Development of educational game-based learning media to improve mastery of ecosystem material in high school students

Pengembangan media pembelajaran berbasis game edukasi untuk meningkatkan penguasaan materi ekosistem pada siswa sekolah menengah atas

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Abstract
Advances in science and information technology currently have a major influence in various fields of life, one of which is the field of education. In the field of education, the implementation of learning in schools should utilize information and communication technology to support the efficiency and effectiveness of learning. Information and communication technologies that can support the learning process in the classroom include educational game learning media. This study aims to develop educational games on ecosystem material for class X SMA. The development model used in this study is the ADDIE model, namely: 1) analysis, 2) Design, 3) Development, 4) Implementation and 5) Evaluation. This study used an instrument in the form of a questionnaire and pretest posttest questions. The questionnaire assessment data were analyzed using quantitative descriptive, while the pretest and posttest data were validated by N-Gain. The results of this study are: game assessment by media experts with an average score of 3.73 (very good), game assessment by material experts with an average score of 3.21 (good), teacher assessment with an average of 3.16 (good), and assessment by students with an average score of 3.09 (good). The results of the students' pretest and posttest based on the N-Gain calculation, namely 0.44 were included in the medium category. Based on the results of the study, it can be concluded that educational games on ecosystem materials for class X SMA are suitable for use as learning media in the classroom based on the results of the feasibility test of media experts, material experts, teachers and students.

Keywords: ADDIE; educational game; ecosystem

Abstrak. *Kemajuan ilmu pengetahuan dan teknologi informasi saat ini berpengaruh besar dalam berbagai bidang kehidupan, salah satunya adalah bidang pendidikan. Pada bidang pendidikan pelaksanaan pembelajaran di sekolah hendaknya memanfaatkan teknologi informasi dan komunikasi untuk menunjang efisiensi dan efektivitas pembelajaran. Teknologi informasi dan komunikasi yang dapat menunjang proses pembelajaran di kelas antara lain yaitu dengan media pembelajaran game edukasi. Penelitian ini bertujuan untuk mengembangkan game edukasi pada materi ekosistem kelas X SMA. Model pengembangan yang digunakan dalam penelitian ini adalah model ADDIE, yaitu: 1) analysis, 2) Design, 3) Development, 4) Implementation dan 5) Evaluation. Penelitian ini menggunakan instrument berupa angket dan soal pretest postest data penilaian angket dianalisis dengan menggunakan deskriptif kuantitatif sedangkan data pretest dan postest dengan validasi N-Gain. Hasil penelitian ini berupa: penilaian game oleh ahli media dengan rata-rata skor 3,73 (baik sekali), penilaian game oleh ahli materi dengan rata-rata skor 3,21 (baik), penilaian oleh guru dengan rata-rata 3,16 (baik), dan penilaian oleh siswa dengan rata-rata skor 3,09 (baik). Hasil pretest dan posttest siswa berdasarkan perhitungan N-Gain yaitu 0,44 termasuk dalam kategori sedang. Berdasarkan hasil penelitian dapat disimpulkan bahwa game edukasi pada materi ekosistem kelas X SMA layak digunakan sebagai media pembelajaran di kelas diluhat dari hasil uji kelayakan ahli media, ahli materi, guru dan siswa. Kata kunci: ADDIE; game edukasi; ekosistem*

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INTRODUCTION

Advances in science and information technology currently have a big influence in various areas of life, one of which is education. In the education sector, the implementation of learning in schools should utilize information and communication technology to support the efficiency and effectiveness of learning. This is in accordance with the learning principles contained in the Primary and Secondary Education Process Standards (Kemendikbud, 2016; Saputra et al., 2017). The use of information and communication technology in implementing the learning process can support the effectiveness of communication. In effective communication learning, teachers and students in the classroom will make it easier to disseminate information or messages in the form of learning materials from teachers to students easily so that it is hoped that the material can be understood well.

There are various ways to convey information or messages from teachers to students, one of which is by using learning media (Anshori, 2019). Learning media is a technology that can be used to send or carry messages in the learning process (Kurniawati & Nita, 2018). In general, the function of learning media is to make it easier for students to capture information and messages conveyed by teachers in classroom learning so that students' knowledge of the learning material carried out in class increases (Nurrita, 2018). According to Munir (2014), learning media is divided into four, namely audio media, visual media, multimedia and object media. Each type of media has its own advantages and disadvantages. So, multimedia is the most effective and efficient media to support learning.

According to Yuliandari (2014), multimedia is media in the form of text, video, animation, graphics, audio and images combined into an integrated whole. Husein et al. (2015) stated that multimedia has advantages and disadvantages. Disadvantages of multimedia include (a) the multimedia development process requires a professional team (b) it takes quite a long time to develop the multimedia. However, multimedia has a number of advantages, namely (a) interactive, making it easier for students to use it, (b) providing an individual affectionate climate, designed so that students do not get bored easily, (c) being able to increase learning motivation, (d) providing feedback and (e) multimedia can be designed for independent learning.

The use of learning media in the form of multimedia by teachers today is generally still limited to using PowerPoint and video displays. This causes the student's learning process to only be limited to listening and seeing the lesson. There is less interaction between students and learning, learning media has more interaction with the teacher. This results in learning becoming boring and less meaningful. The material delivered by teachers to students is captured and understood by students in short-term memory, so that students' understanding of the material presented is lacking. Based on research conducted by Kurniawati & Nita (2018) it is stated that one of the causes of low student learning outcomes in class is due to the lack of use of multimedia-based learning media. To overcome this, the learning media that is suitable for use in learning is educational games. According to Panjaitan et al. (2020), multimedia learning media that allows students to be interactive in learning is educational games.

Educational games are combine images, text, sound, video and animation containing computer-based learning material to make it easier to understand concepts and make it easier to present the material (Kevin, 2017). According to Yulianti & Ekohariadi (2020), in general educational games also have advantages and disadvantages. The advantages are (a) it makes the learning process easier, (b) it invites children to learn earlier and (c) it is a fun learning tool for children. Meanwhile, the disadvantages are (a) minimal interest, (b) monotonous gameplay, (c) small number of educational game providers and (e) low market.

The use of educational games in the learning process has been widely reported from PAUD to high school. The results of Vitianingsih (2017) research show that educational games in the learning of children aged 3-6 years are very influential in making it easier for children to understand symbols, letters, and matching symbols or images and make it easier for teachers to change children's way of learning from conventional learning to conventional learning simulation. Research by Ramadhani et al. (2016) shows that the educational games developed are in the valid category and are suitable for implementation in the classroom. The learning process using educational games in the classroom has been proven to increase junior high school students' interest in learning in science subjects as seen from the results of assessing student interest in learning with a percentage result of 92.1% in the good category. Pramuditya et al. (2018)

research conducted on high school students showed that the validation results of educational games were very valid, and the average percentage of students showed good (high) numbers.

In biology learning, material can be conveyed easily and clearly to students if the teacher uses educational games as a learning medium (Citrasukmawati et al., 2012). Educational games were chosen because in biology learning there are many events that can be described through educational games so that they attract students' attention and students understand them more easily. The research results of Rianingtias (2019) show that learning using educational games in biology learning gets good results from students, learning is more effective because students are interested in the educational game media displayed. This reduces the possibility that students will not understand the learning in class. There are several factors that influence students' lack of understanding in class, including the lack of interest in the learning process in class, teachers being too quick in discussing the material taught in class and students not paying attention because they are engrossed in their own activities.

In Ecosystem material, the use of educational games is deemed necessary, because with educational games on ecosystem material, several points that are still difficult for students to understand, such as the sub-material of biogeochemical cycles, will be easier to understand. The use of educational games as a learning medium is expected to increase students' mastery of the material because students can observe and pay attention when the learning process takes place with learning that is interesting for students.

The results of research by Kurniawati & Nita (2018) show that the application of learning media in schools has a significant influence on mastery of the material. The increase in students' mastery of the material occurs due to the increase in the learning process in the classroom which makes students more active in the learning process. Research by Setiawan & Napitupulu (2015) states that the learning process can be improved by applying media in the learning process. By applying media in the learning process in class, it can influence student activity in class and make learning more enjoyable.

Based on the results of an interview with one of the biology teachers at SMA N 1 Cisaga who stated that the school was experiencing difficulties in the learning process, especially in attracting students' interest and attention to pay attention to the teacher when delivering material in class. In general, teachers at SMA N 1 Cisaga still use PowerPoint media in the classroom learning process, so students easily get bored when the teacher delivers the material. In biology learning, especially regarding ecosystem material, teachers still deliver material using PowerPoint media, even though there are many media that can be used to convey ecosystem material in classroom learning, one of which is educational games. However, most teachers do not understand how to deliver learning media using educational games. Therefore, it is necessary to develop educational game-based media to improve students' mastery of material in biology learning classes. Based on this description, researchers are interested in conducting research with the title "Development of educational game-based learning media to improve mastery of ecosystem material in high school students".

RESEARCH METHOD

This research was carried out using a fairly systematic development model, namely the ADDIE development model. In this learning model there are five steps, namely: (1) analysis, (2) design, (3) development, (4) implementation, and (5) evaluation (Tegeh et al., 2015).

The stages of the ADDIE development model process are:

1) Analysis: At the analysis stage, activities are carried out, namely (a) analyzing basic competencies, indicators and learning objectives that must be mastered by students, (b) analyzing student characteristics related to the use of ICT such as the use of cellphones and laptops, (c) analyzing learning media used in schools, (d) analyze the scope of ecosystem materials.
2) Design: At this stage the focus is on the continuation of the analysis stage, namely: (a) preparing the material, (b) designing the storyboard, and (c) creating the game design.
3) Development: At this stage, we start to focus on the game creation process, such as collecting image assets, animations, buttons. Game preparation was also carried out using Adobe Illustrator CS6 and Unity software. Then the media expert and material expert validation stage was carried out.

4) Implementation: The next stage is implementation in the learning process to determine the suitability of educational games for teachers and students which are prepared through a questionnaire as an assessment instrument.
5) Evaluation: The final stage is to carry out an evaluation by collecting data in the form of assessment instruments (questionnaires) for teachers and students regarding the quality of the games presented. From this data it can be seen whether the game displayed is suitable for use or not.

The questionnaire assessment instrument consists of 29 statement items for students, 28 statement items for teachers, 15 statement items for material experts, and 30 statement items for media experts. The questionnaire uses a questionnaire with a Linkert scale type, which consists of four scales: DA (Disagree) with a score of one, LA (Less Agree) with a score of two, A (Agree) with a score of three, and SA (Strongly Agree) with a score of four apart from the questionnaire, data collection was also carried out using pre-test and post-test questions, which consisted of 15 multiple choice questions and five description questions.

In this research, double methods were used to carry out data analysis, namely quantitative descriptive data analysis and qualitative descriptive data analysis. Quantitative descriptive data analysis was used to determine the feasibility of educational games based on data obtained from questionnaires from media experts, material experts, biology teachers and students. Qualitative descriptive analysis aims to determine the assessment of digital educational games as seen from comments and suggestions provided by media experts, material experts, biology teachers and students. The data analysis stage is changing the qualitative questionnaire results to quantitative using a Linkert scale, and determining the average score for each statement based on Table 1.

Table 1 Educational Game Assessment Criteria

Score Interval	Criteria
Mi + 1,5 Sbi < X	Very Good
Mi + 1,5 Sbi < X ≤ Mi + 1,5 Sbi	Good
Mi - 1,5 Sbi < X ≤ Mi + 1,5 Sbi	Good Enough
Mi - 1,5 Sbi < X ≤ Mi + 1,5 Sbi	Less Good
X ≤ Mi – 1,5 Sbi	Not Good

(Source: Risnani & Adita, 2018)

Information:
X : Actual score average
Mi : Ideal Mean
Sbi : Ideal standard deviation
Mi : 1⁄2 x (Ideal highest score + Ideal lowest score)
Sbi : 1⁄6 x (Ideal highest score – Ideal lowest score)

Next, a data analysis test was carried out to determine students' mastery of Ecosystem material in biology learning using digital educational game media. Data obtained from students' mastery of the material was analyzed using the N-Gain test which was calculated using Formula 1. The calculation results using this formula were then categorized based on Table 2.

$$\text{N-Gain} = = \frac{Score\ Post\ Test - Score\ Pretest}{Score\ Maksimal\ Ideal - Score\ Pretest} \quad \text{.....Formula 1}$$

Table 2 N-Gain Assessment Guidelines

Gain Index Value	Category
N-Gain> 0,70	High
0,30 < N-Gain ≤ 0,70	Medium
N-Gain ≤ 0,30	Low

(Source: Dewi et al., 2017)

RESULTS AND DISCUSSION

Result

The development of digital educational games using the ADDIE development model obtained the following results:

1. Analyse

a. Analysis of KD, indicators, and learning objectives

The basic competency (KD) and indicators chosen in class X Biology learning are KD 3.9 with Ecosystem material. The development of indicators aims to achieve learning objectives by using educational game learning media. The indicators of KD 3.9 and the learning objectives are shown in Table 3.

Table 3 Learning Indicators

No	Learning Indicators	Instructional Goal
1	Find ecosystem components in the surrounding environment	Students can discover the components of ecosystems in the surrounding environment
2	Distinguish between ecosystem components in the surrounding environment	Students can differentiate between ecosystem components in the surrounding environment
3	Explain the relationship that occurs between biotic and abiotic components in the surrounding environment	Students can explain the relationship that occurs between biotic and abiotic components in the surrounding environment
4	Explain the food webs in the surrounding environment	Students can explain about food webs in the surrounding environment
5	Explain biogeochemical cycles (phosphorus cycle, nitrogen cycle, sulfur cycle, water cycle and carbon and oxygen cycle)	Students can explain biogeochemical cycles (phosphorus cycle, nitrogen cycle, sulfur cycle, water cycle and carbon and oxygen cycles)
6	Create a food web chart that occurs in the surrounding ecosystem	Students can create a food web chart that occurs in the surrounding ecosystem

b. Student analysis

In general, students at SMA N 1 Cisaga are used to using cellphones. Most use cellphones as a communication tool, for entertainment such as playing games or for learning in class. In the learning process in class, cellphones are usually used to search for learning material that students do not understand. However, it is often misused by students to play non-educational games during class.

c. Analysis of learning media used in schools

The learning media carried out at SMA N 1 Cisaga is generally still limited to using PowerPoint and video displays. This results in learning in the classroom becoming boring and a lack of interaction between teachers and students. So that students will remember the learning material taught by the teacher in the short term.

d. Analysis of the scope of ecosystem material

The scope of material that is considered necessary to be compiled in learning media includes ecosystem components, life organization, interactions between components, material flow, energy and biogeochemical cycles.

2. Design

a. Preparation of material

The preparation of this material aims to make it easier to select material for digital educational game learning media. The Ecosystem material consists of: Ecosystem Components, Organization of Life, Interactions between components, Flow of Matter and Energy and Biogeochemical Cycles.

b. Storyboard design

Storyboard design is the design stage of the overall game design in sketch form. The purpose of making storyboards is to make it easier to create games or animations. The storyboard for the educational game "Summer Camp" can be seen in Figure 1.

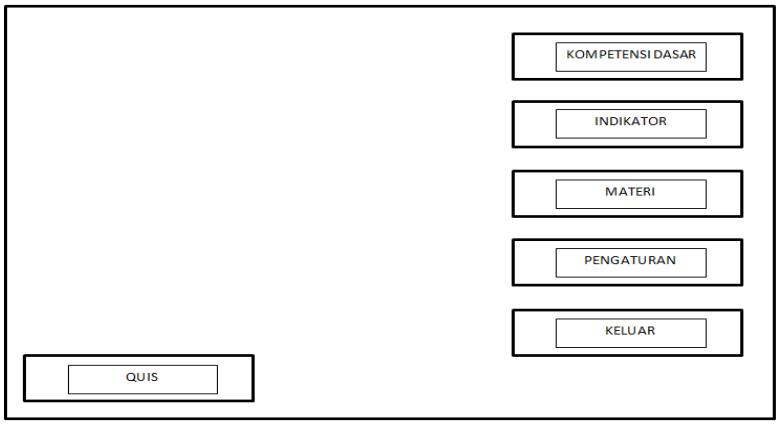


Figure 1
Storyboard Design (in Indonesian)

c. Create game designs

At this stage, game assets begin to be arranged and adapted to the storyboard that has been created. The game assets compiled include buttons, backgrounds, sounds, characters and materials. Having game assets will make it easier and faster to design games with the Adobe Illustrator CS6 application and the Unity application.

3. Development

At this stage, the game is prepared using the Adobe Illustrator CS6 application and the Unity application with the appearance as in Figure 2 to Figure 15.



Figure 2
The home page contains a welcome greeting, title and identity



Figure 3
The menu page contains the KD button options, indicators, materials, settings, and exit (in Indonesian)



Figure 4
The basic competency page contains KD 3.9 and 4.9 (in Indonesian)

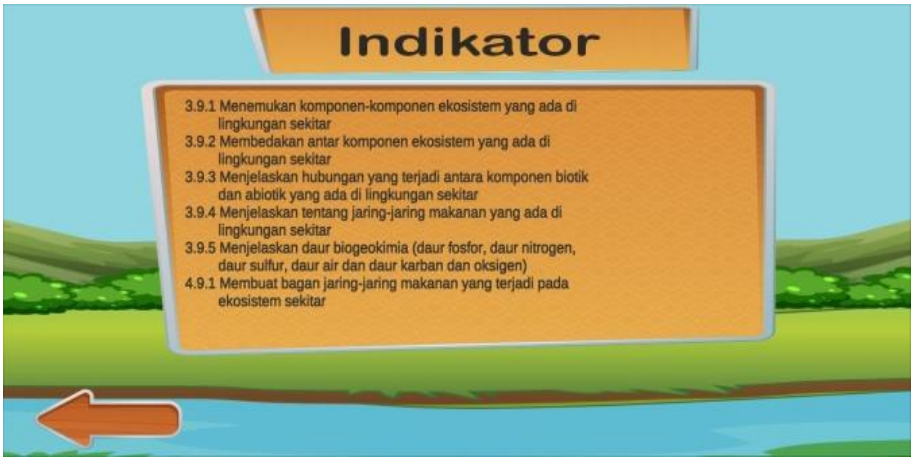


Figure 5
The indicators page contains indicators from KD 3.9 (in Indonesian)

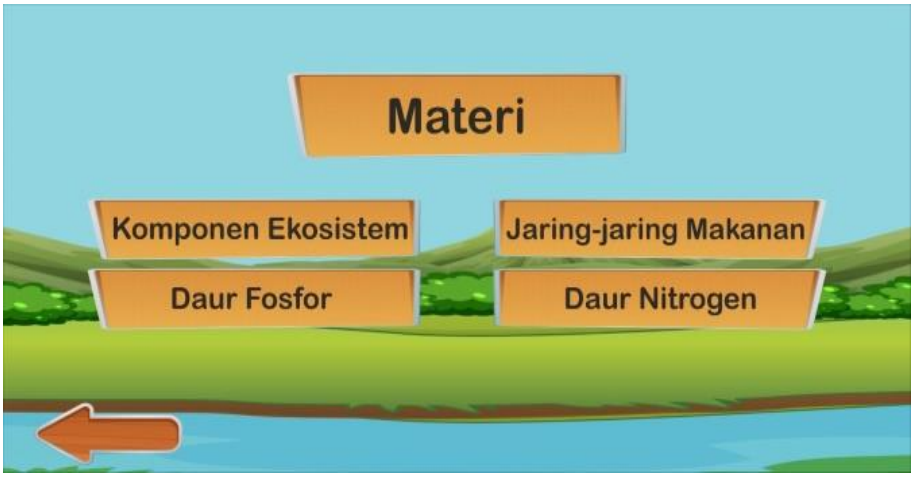


Figure 6
The material menu page contains ecosystem sub-material options (in Indonesian)

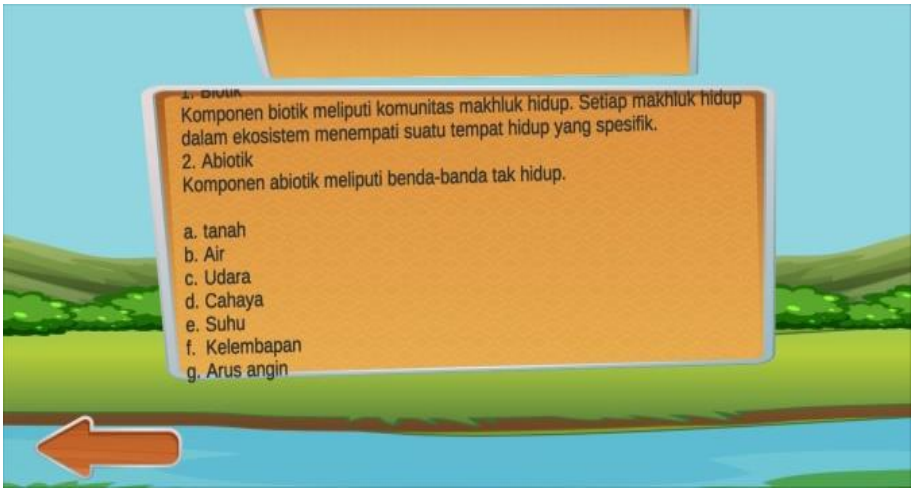


Figure 7
The material page contains the contents of the ecosystem material (in Indonesian)



Figure 8
The game menu page contains a selection of games from the ecosystem material (in Indonesian)

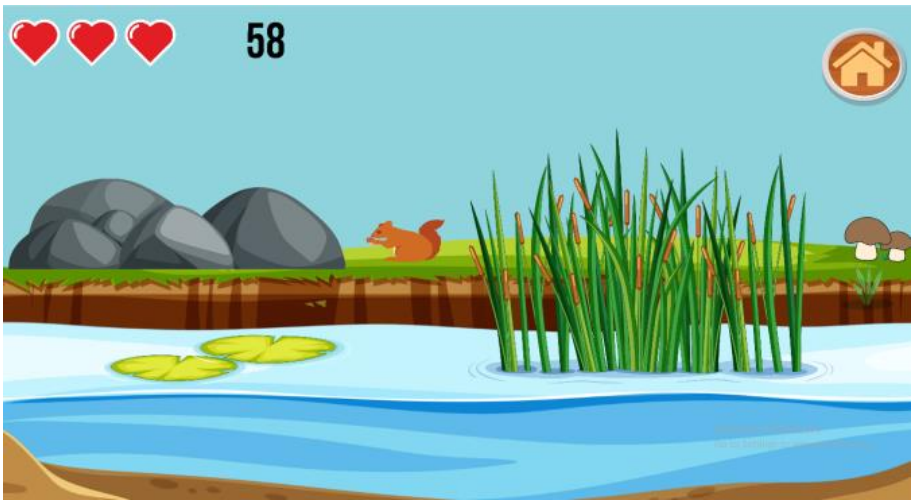


Figure 9
The game material page contains educational games that students must play (in Indonesian)

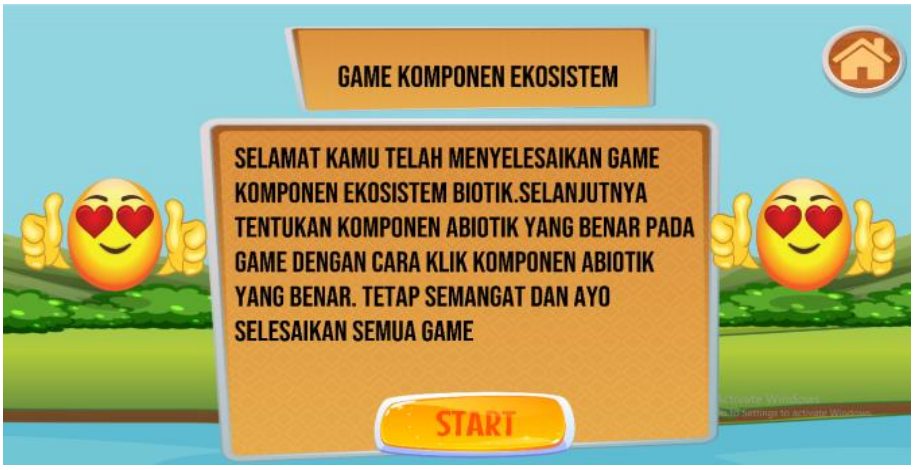


Figure 10
The feedback page actually contains feedback on the results of the games played by students if they are successful (in Indonesian)



Figure 11
The feedback page actually contains feedback on the results of the games played by students if they fail (in Indonesian)



Figure 12
The evaluation page contains evaluation questions on ecosystem material (in Indonesian)



Figure 13
The final results display contains the final score of the ecosystem material evaluation questions (in Indonesian)

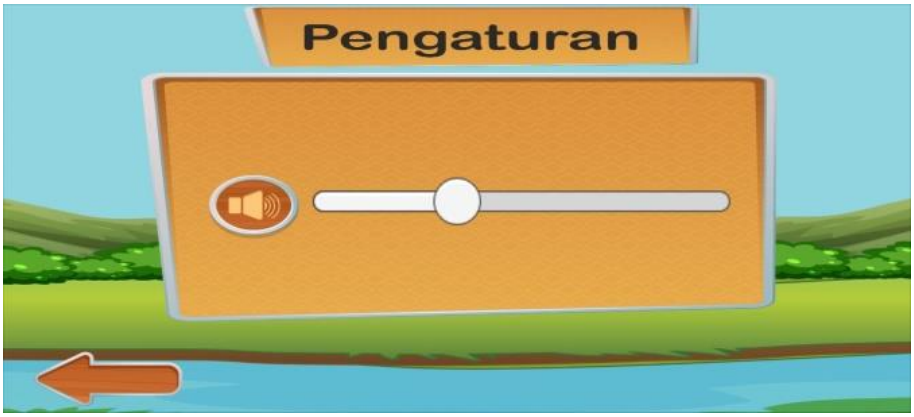


Figure 14
The settings display contains sound volume measurements (in Indonesian)



Figure 15
The exit menu display contains options for exiting the educational game (in Indonesian)

Educational games that have been developed and validated by media experts and material experts have obtained results as shown in Figure 16 and Figure 17.

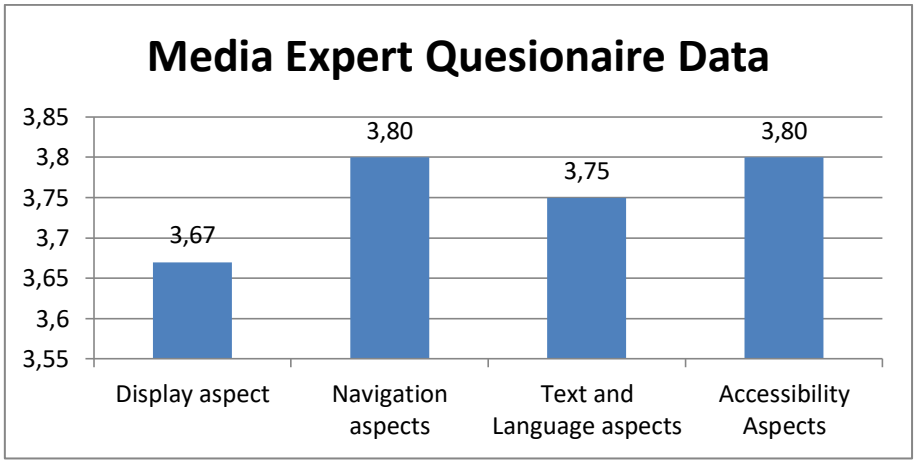


Figure 16
Graphic of media expert responses

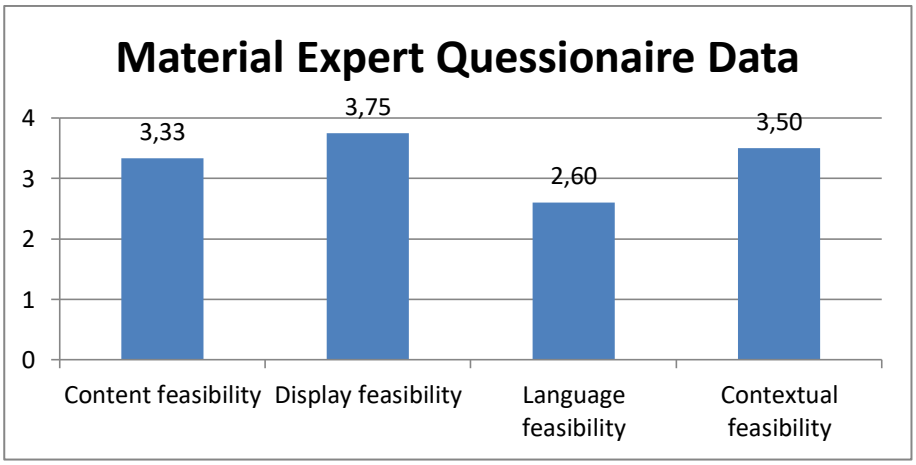


Figure 17
Graphic of material expert responses

The media expert validation results show that the total score obtained is 3.73 (very good), with an average display aspect score of 3.67 (very good). In the navigation aspect, the average was 3.80 (very good). In the text and language aspect, the average was 3.75 (very good). In the accessibility aspect, the average was 3.80 (very good).

The results of the material expert validation showed that the total score obtained was 3.21 (good), with an average content feasibility aspect score of 3.33 (very good). In the aspect of appropriateness of presentation, the average was 3.75 (very good). In the aspect of language appropriateness, the average was 2.60 (good enough). In the aspect of contextual suitability, the average was 3.50 (very good).

4. Implementation

Implementation is known based on data from teacher assessment questionnaires in Figure 18, student assessment questionnaires in Figure 19, and N-Gain scores in Figure 20. The results of the teacher's validation showed that the total score obtained was 3.16 (good), with an average display aspect score of 3.13 (good). In the navigation aspect, the average was 3.20 (good). In the text and language aspect, the average was 3.27 (very good). In the material quality aspect, the average was 3.16 (good). In the instructional/learning aspect, they obtained an average of 3.20 (good). In the accessibility aspect, the average was 3.12 (good). The validation results by students showed that the total score obtained was 3.09 (good), with an average score for the learning objectives aspect of 3.07 (good). In the material quality aspect, the average was 3.19 (good). In the appearance aspect, it obtained an average of 3.09 (good).

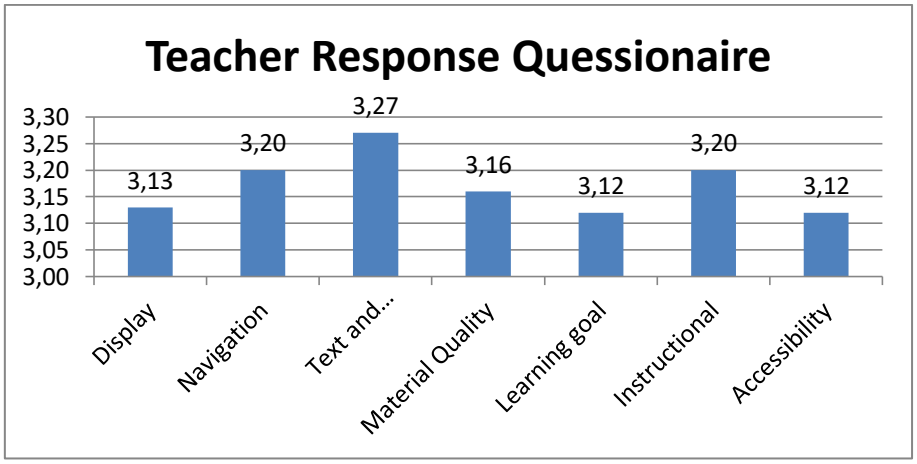


Figure 18
Teacher response graph

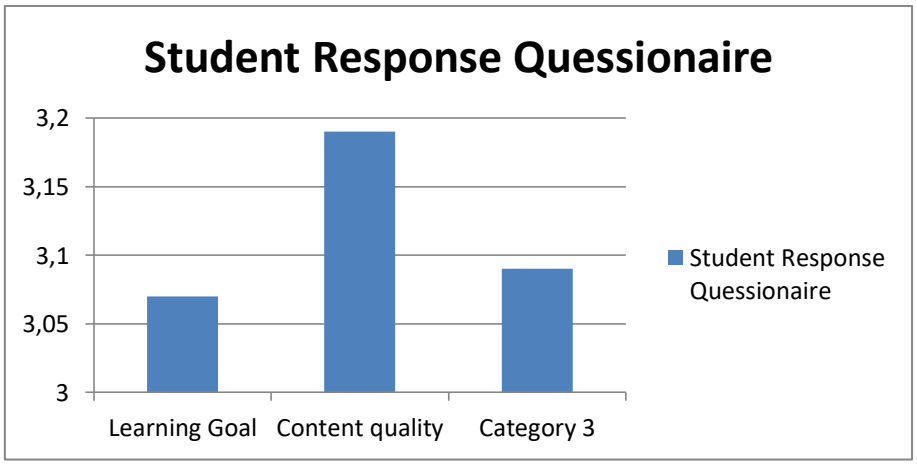


Figure 19
Graph of student responses

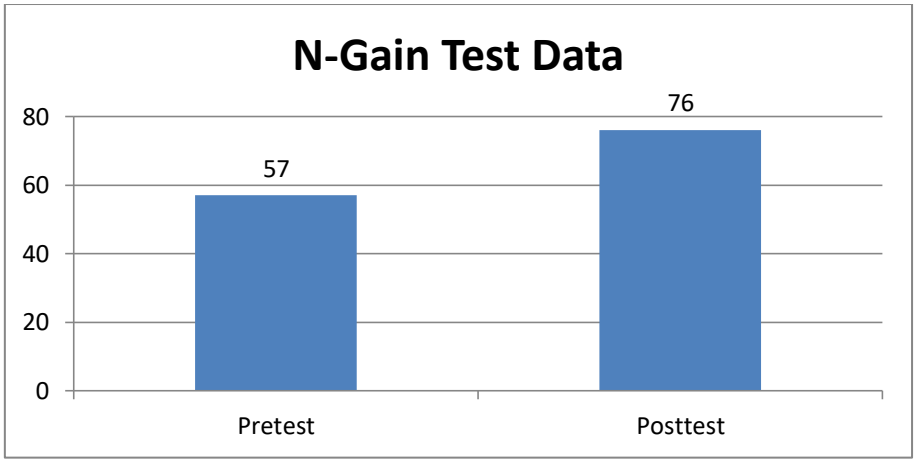


Figure 20 Pretest and posttest assessment graph (N-Gain Test)

In the N-gain Test assessment there are pretest and posttest questions with a result of 0.44 (Medium). Learning using digital educational game media in class X Ecosystem material at SMA N 1 Cisaga shows an increase in students' mastery of the material in class. The application of digital educational games in Biology learning in class begins with working on questions in the form of a pretest with an average score

of 57. After applying digital educational games as a learning medium, a posttest is carried out with an average score of 76.

5. Evaluation

The final stage in developing the ADDIE model is the evaluation stage. At this stage it can be seen from the results of the assessment, comments and suggestions provided by media experts, material experts, teachers and students. From this it can be concluded that the digital education game used as a Biology learning medium in class is suitable/not suitable for use as a Biology learning media with Ecosystem material for class X SMA.

Discussion

Based on research that has been carried out on the development of digital educational games for Biology learning for class X SMA, the Ecosystem material has been validated by media experts and material experts with good assessments. Media expert validation with an average score of 3.73 is included in the very good category, because it is in the interval 3.25 > According to Primasari et al. (2015) learning media must be fun, interesting and more varied so that students will more easily accept the material presented.

Validation by material experts obtained an average total score of 3.21, which is in the good category, because it is in the interval $2.75 < X \leq 3.25$. The material expert also added comments and suggestions to the game that the learning method with educational games is very relevant to current technology, and it is recommended to add more examples to the material in the game. According to Mahtarami & Ifansyah (2015) learning media with educational games are very effective in the learning process, this is based on: (a) the use of actions to replace verbal explanations of material, (b) creating motivation and personal satisfaction, (c) accommodating a variety of learning styles and skills, (d) emphasize mastery of skills, and (e) provide an interactive context in decision making.

After validating with media experts and material experts, it is then applied to schools for learning activities. The educational game assessment stage was carried out by five different teachers at SMA N 1 Cisaga. The assessment results obtained from the overall teacher assessment with an average of 3.16. The results of this assessment are included in the good category, because the average score obtained is in the score range $2.75 < X \leq 3.25$. The teacher also adds comments and suggestions to the game that the presentation of the material with the method used is appropriate to the nature of the delivery and objectives. And it is recommended that students pay more attention when applying educational games in the classroom. According to Panjaitan et al. (2020) when delivering material in educational games, it is necessary to pay attention to conceptual and theoretical truth. Apart from that, the depth of the material and the sequence of the material also influence students so that the delivery is in accordance with the student's level of knowledge and in accordance with the sequence of the material. Using educational games will make it easier for students to study independently in class and at home, besides that, educational game learning media is also expected to make it easier for students to explain material in class.

Students also assessed the game, the assessment was carried out by class X students with a total of 26 students. The assessment results were obtained from the overall student assessment with an average of 3.09. Included in the good category, because the average score obtained is in the range of $2.75 < X \leq 3.25$. The implementation of educational games in class has a good influence on the learning process, seen from students' mastery of ecosystem material. Students' mastery of the material can be seen from the pretest and posttest carried out before and after learning using educational game media in class. Based on the results of the pretest and posttest calculations using the N-Gain calculation from the pretest and posttest scores, the results of the posttest scores were better compared to the pretest results. With a total N-Gain calculation result of 0.44, it shows that educational games have a moderate influence on the learning process in class using educational game learning media.

Similar research was conducted by Setiawan & Napitupulu (2015); Putra et al. (2016) which states that the learning process can be improved by implementing media in the learning process in the classroom. By applying media in the learning process in class, it can influence student activity and make learning more enjoyable. So it will be easier for students to capture learning material in class and will increase students' mastery of the material. Research from Yustin et al. (2016) showed that student learning outcomes

increased 32% from before using educational game applications. This result is higher than the use of book learning media which only increased by 28%.

The harmony between the results of this research and previous studies proves that learning using educational games has a positive impact on students. According to Yulianto & Putri (2020) educational games are a fun learning medium for students. Widya et al. (2021) explained that apart from being fun, educational games are effective in increasing students' learning motivation, are easy to use, and the material is easier to understand.

CONCLUSION

Based on the results of research conducted at SMA N 1 Cisaga in the learning process using educational game learning media, the average results from media experts were very good, assessments from material experts were good, assessments from teachers were good, and assessments from students were good. From this assessment, educational games with Ecosystem material are suitable for use and implementation in classroom learning. Based on the results of implementation in class, it shows that educational games have an effect (Medium) on students' mastery of the material in class as seen from the results of the students' pretest and posttest on ecosystem material.

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