Development of Android-Based Educational Games to Improve Students' Learning Outcomes in Hydrocarbon

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Abstract: Android-based educational game is a game using a smartphone operating system with certain teaching materials as learning media in an interesting, unique, and fun. The purpose of this study was to produce educational game media product that are feasible and valid. This development research used the ADDIE model (analyze, design, developt, implementation, and evaluation). The results of the study: (1) the media expert's validity value was 96.6% in the very feasible and very valid category, (2) the material expert's validity value was 91.4% in the very feasible and very valid category, and (3) the results of the students' readability test was 93.6% in the very feasible and very valid category, (4) N-Gain score of 0.84 in the high category and an effectiveness level of 84.6% in the "effective" category. Therefore, the android-based educational game media was effectively used to improve student learning outcomes with high effectiveness.

Keywords: educational game, chemistry learning, ADDIE.

Abstrak: Game edukasi berbasis android merupakan permainan menggunakan sistem operasi smartphone dengan materi ajar tertentu sebagai media pembelajaran dengan menarik, unik, dan menyenangkan. Tujuan penelitian ini adalah untuk menghasilkan produk media game edukasi yang layak dan valid. Penelitian pengembangan ini menggunakan model ADDIE (analyze, design, developt, implementation, and evaluation). Hasil penelitian: (1) nilai kevalidan ahli media sebesar 96.6% dengan kategori sangat layak dan sangat valid, (2) nilai kevalidan ahli materi sebesar 91.4% dengan kategori sangat layak dan sangat valid, dan (3) hasil uji keterbacaan peserta didik sebesar 93.6% dengan kategori sangat layak dan sangat valid, (4) Skor N-Gain sebesar 0.84 dengan kategori tinggi dan tingkat efektifitas sebesar 84.6% dengan kategori "efektif". Oleh karena itu, media game edukasi berbasis android yang diterapkan efektif digunakan untuk meningkatkan hasil belajar siswa dengan efektifitas tinggi.

Kata kunci: game edukasi, pembelajaran kimia, ADDIE.

▪ INTRODUCTION

The integration of digital technology in learning, especially chemistry, is a challenge for teachers in the current digital era in utilizing information and communication technology as a more sophisticated facility to expedite the learning process (Meenakshi, 2013; Widarti et al., 2022). The rapid development of this technology is marked by the increasing use of electronic devices, one of which is the smartphone which is the current trend and is most in demand by students because it has the Android operating system (Sirhan, 2007; Ghavifekr & Rosdy, 2015; Lubis & Ikhsan, 2015; Ferento, 2017). Facilities in technology are increasingly rapidly enabling the provision of material outside the classroom so that students can learn independently with the aim of encouraging individual involvement to better support and enhance their activities. (Esson, 2016; Xi & Hamari, 2019), especially in science material such as

chemistry. An example of using science education technology is the use of software such as Moodle, Google classroom, website-based learning media, Wordwall and Edmodo (Franklin & Smith, 2015). The use of this software when combined with gamification in learning can improve the learning process and the results that support the mastery of 21st century student skills (Codish & Ravid, 2015; Manjale & Abel, 2017; Caporarello et al., 2019; Kimianti & Prasetyo, 2019). However, utilization of android as a learning resource that has not been used optimally makes students operate smartphones more to play games and surf social media, even though the use of android as a learning resource can be used as a media tool that can increase students' interest in learning. Teachers must have a creative way of growing interest in learning and motivation to learn in students because it is one of the keys to successful achievement of learning objectives. Therefore, the habits of students who really like or like playing games can influence the learning styles of students.

Learning styles are the easiest way for each individual to capture, organize, and manage the information received. The fact is that in learning activities students need to be assisted and directed to identify appropriate learning styles so that learning objectives can be achieved effectively (Bire at al., 2014). Based on research conducted by Rahyuni at al, (2021) shows that games are often played by students starting from the elementary, middle and high school levels so that it will have an impact on students' learning styles which affect their motivation and learning outcomes. Research conducted by Sari, et al (2017) game players with a percentage of 80% are aged 12-21 years, namely teenagers. This is in line with research conducted by Putri, et al (2022) that learning with fun game media can motivate student learning. Therefore, it is necessary to develop educational game learning media based on Android that can help and support students in understanding and learning the material provided by the teacher.

Teachers are aware that without the help of learning media, teaching materials will be difficult to digest and understand by students, especially on chemical hydrocarbons (Sozbiler & Pynarbapy, 2010; Kamisah & Nur, 2013; Woldeamanuel at al., 2014). The potential for game content that contains scientific chemical content such as hydrocarbons is well designed to be able to improve the teaching and learning process that is more meaningful and easy for students to understand (Wang & Zheng, 2020). Hydrocarbon is a chemical material which is a prerequisite concept for the next material concept. If the concept of hydrocarbons is not mastered correctly at the beginning of grade 11, students will have difficulty learning the next material concept. According to Pratiwi et al, (2013) the characteristics of hydrocarbon material include: (1) Hydrocarbon material contains many and varied facts and terms that students must memorize; (2) The terms in the hydrocarbon material are generally in the form of names of compounds that are very foreign to students because they are not found in everyday life; (3) Hydrocarbon material is dense material, so it takes a longer time to deliver the material in class. Therefore, media is needed that can help students understand hydrocarbon material such as the development research conducted by Fitriyana et al, (2018) which developed chemistry learning media in the form of a hydrocarbon hybrid-learning and android-based-game.

Educational games are effective learning tools or media that can be developed so that they can assist teachers in conveying material and designing a learning system to increase student enthusiasm and desire to learn (Fatimah, 2014; Nenohai et al., 2022).

Therefore, the teacher's ability to design and develop instructional media is very important, so that the role of the game makes students more focused and trains sportsmanship in solving problems quickly and precisely (Birney at al., 2017).

The use of educational games in learning is still rarely found even though they already exist, but their use as learning media is still lacking (Setiawan et al., 2019). Android-based educational games are one of the interesting and interactive learning media that prioritize collaboration, communication, and can lead to interaction between students. Game media has characteristics that can create student learning motivation, namely fantasies, challenges and curiosity. Android-based educational games will be developed using the drag and drop method in educational games which will produce good media for learning (Wijaya et al., 2020). This is in line with research conducted by Aryani and Hartina (2017) who developed a hydrocarbon game in which the application is loaded in a game of compiling the chemical structure of carbon using multimedia techniques with a drag and drop system which can train students to solve a problem in the right and correct way fast.

Based on the research that has been done before, the development of educational game media will be designed with three levels of each hydrocarbon sub-material containing content of hydrocarbon material with the type TTS, drag and drop, choose hydrocarbons, and find hydrocarbons. The science of pedagogy or instructional design embedded in games should play an important role to make classroom learning more effective. Based on the advantages of android-based educational games as stated above, the researcher is interested in conducting development research with the title "Development of Android-Based Educational Games on Hydrocarbon Material to Improve Student Learning Outcomes."

Research Question

The following a main research questions that the study seeks to answer: (1) What are the results of the development of Android-based educational game media products on decent and valid hydrocarbon materials?

▪ **METHOD**

The research method used to develop learning media in the form of android-based educational games on hydrocarbon material is Research and Development or R & D. The design for developing learning media in the form of android-based educational games uses the ADDIE model which consists of 5 stages, namely Analysis, Design, Development, Implementation, and Evaluation (Surjono, 2017).

The following are five stages of research on the development of android-based educational game media using the ADDIE model: (1) Analyze, namely analyzing students' problems or needs by observing the learning process on the use of learning media. The results of the analysis of problems in the use of smartphones that have not been used optimally, so it is necessary to develop a learning media that can help the learning process; (2) Design, namely the design activity includes three stages: making flowcharts and storyboards; preparation of material content, questions, games and discussions; preparation of validity instruments; (3) Develop, the media development stage uses Adobe Flash Player 11 and Canva software, as well as validation from media experts and material experts; (4) Implementation, after the game media has been

validated, it is continued with a student readability test by thirty-three students of class XII IPA 3 and a test of the effectiveness of the media game by students of class XI IPA 4 of thirty four people to improve student learning outcomes. This test is carried out in the odd semester of the 2022/2023 school year; (5) Evaluation, this stage revision of educational game media products is carried out. Evaluation of the results of the data on the responses of students and observers was processed so that an overview of the game media being developed was obtained.

Participants

The population in this study were all students of class XI IPA Malang Laboratory High School. The sampling technique in this study used a cluster random sampling technique, obtained by class XI IPA 4 as the research sample consisting of 34 students.

Instruments

The research instrument consisted of treatment instruments and measurement instruments. The treatment instruments include syllabus, lesson plans, worksheets, and android-based educational game media. Before being used as a treatment instrument, a validity test was carried out first by three validators, namely two chemistry lecturers and one chemistry teacher. Measurement instruments include learning outcomes tests (pretest and posttest). According to Arikunto (2012: 47) the test is an information gathering tool, but when compared to other tools, the test is more official. Therefore, this study uses the test as an instrument to determine student learning outcomes.

The learning outcomes test questions consist of 40 questions which are then validated by experts and empirical validation. Based on calculation results of expert validity, percentage of 99% is obtained with a very high category. Based on the results of the item validation calculations, 20 valid questions were obtained and 20 invalid questions were obtained. Based on the results of calculating the reliability of the questions, the reliability results obtained were 0.804 with the "very high" level of reliability category.

Data Analysis

After the game media validation process by the validator, the results of the media validity percentage by Riduwan (2015) are categorized based on the criteria in Table 1.

Table 1. Media validity criteria

Percentage (%)	Information
81-100	Excellent
61-80	Good
41-60	Moderate
21-40	Poor
0-20	Very Poor

The percentage of scores from the validation and student readability test are interpreted to analyze the feasibility of the product. The product is said to be feasible if it obtains a score percentage of $\geq 61\%$. The percentage analysis eligibility criteria by Riduwan (2012) can be seen in Table 2.

Table 2. Percentage analysis eligibility criteria

Percentage (%)	Information
0 - 20	Not feasible
21 - 40	Less worthy
41 - 60	Decent enough
61 - 80	Worthy
81 - 100	Very worth it

N-Gain Score

N-gain is used to measure the increase in learning outcomes before and after learning. The difference in pretest and posttest scores is thought to be due to the effect of the treatment. Furthermore, N-Gain normalization gain is classified into three categories, namely:

Table 3. Classification of n-gain values

Value Range	Classification
$g > 0.70$	High
$0.30 \geq (g) < 0.70$	Medium
$g < 0.30$	Low

While the division of categories for the acquisition of N-gain values in the form of percent (%) can refer to Table 4.

Table 4. N-Gain effectiveness level category

Percentage (%)	Category
<40	Ineffective
40-55	Less effective
56-75	Effective enough
>76	Effective

▪ **RESULT AND DISSCUSSION**

Development Results of Android-Based Educational Game Media

The media development research data was obtained from the results of filling out validation sheets by two media experts, two material experts, and a number of respondents or students to assess the feasibility results of the developed Android-based educational game media. Before the respondents filled out the assessment instruments provided, each respondent first tested the educational game media that had been developed. The results of the validation test by media experts were in the form of responses and assessments from media experts, then the results of the data obtained were analyzed and product revisions were carried out according to the suggestions.

The educational game media that has been developed consists of 3 sub-materials, namely the characteristics of carbon atoms, structure and nomenclature of hydrocarbon compounds, and isomers of hydrocarbon compounds with 3 different levels. The following is an example of a game finding hydrocarbons in the specificity submatter of level 2 carbon atoms.

Figure 1. Level 2 Finding Hydrocarbons

In addition to the appearance of the level two game on the uniqueness of carbon atoms, in the sub-matter of structure and nomenclature of hydrocarbon compounds at level 1 and 2 using the Crossword Puzzle (TTS) method can be seen in Figure 2.
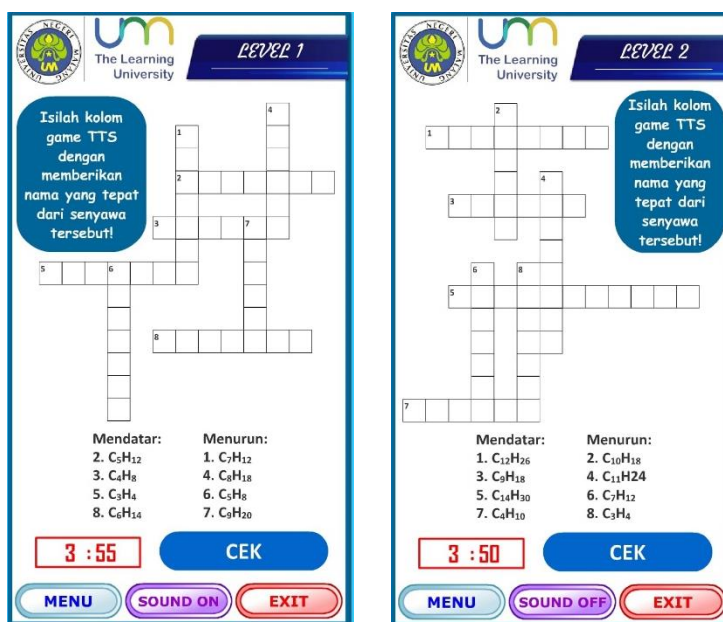

Figure 2. Level 1 and 2 the crossword puzzle (tts)

The appearance of the game on level 3 isomers of hydrocarbon compounds uses the drag and drop method, where students can assemble their own carbon chains to form isomer chains of hydrocarbon compounds. This game can train students' imagination in representing carbon chain compounds.
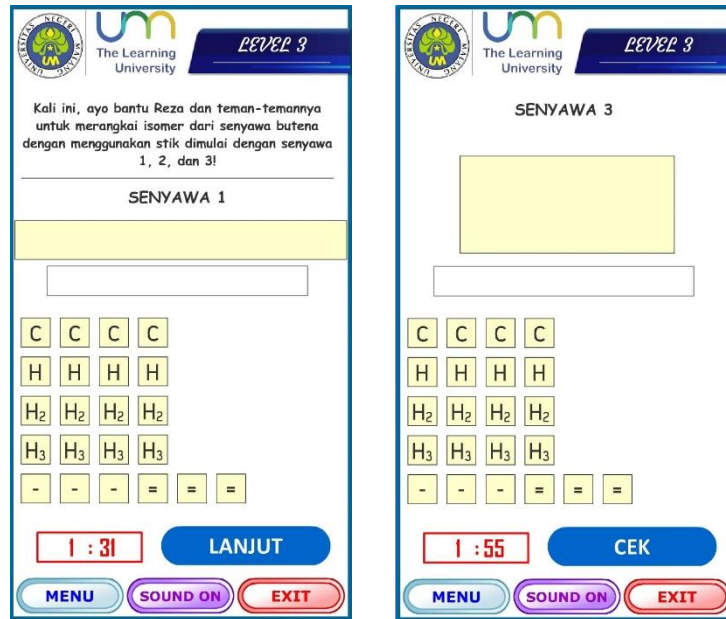
Figure 3. Level 2 and 3 *drag and drop*

Results of Validation by Media Experts

The validation process by the educational game media expert validator was carried out by two media expert validators who are experts in the field of media development, namely one chemistry lecturer and one educational technology lecturer at State University of Malang. This validation aims to measure the level of validity and feasibility of the educational game media that has been developed, suggestions and input are used as a revision of the educational game media. The aspects assessed at the media expert validation stage are attention-grabbing materials, interactiveness, and others. The following results of the validation of media experts can be seen in Table 3 below.

Table 3. Media expert validation results

No.	Indicator	Percentage	Criteria
1.	Attention Material	97%	Very Valid
2.	Interactivity	96%	Very Valid
3.	Etc	94%	Very Valid
	Average Score	**96.6%**	Very Valid

Based on the percentage of validator assessment data, media expert validation has a percentage of 96.6% with a very decent media feasibility category. In addition to the scoring data in the form of numbers, there is an assessment of qualitative data in the form of criticisms and suggestions submitted by each validator. Critical qualitative data and suggestions from a material perspective can be seen in Table 4.

Table 4. Criticism and suggestions by media expert validators

No.	Criticism and Suggestions
1	In general, the media is valid and feasible to use at the next research stage

2	When the user tries to fill in the TTS, try to keep the formula where the name will be written (not covered by the smartphone keyboard)

Criticism and suggestions for improvement from media experts contained in the validation sheet are taken into consideration and the basis for improvement in terms of the media. Improvements aim to reduce errors in the developed educational game media.

Results of Validation by Material Experts

The validation process by material expert validators in educational games is carried out by three material expert validators who are experts in the field of chemistry, namely two chemistry lecturers at State University of Malang and a chemistry teacher at Laboratory High School Malang. This validation aims to measure level of validity and feasibility of material in educational games that have been developed, suggestions and input are used as revisions to material content in educational game media. The following results of expert validation of educational game material can be observed in Table 5.

Table 5. Material expert validation results

No.	Indicator	Percentage	Criteria
1.	Material Presentation	87.45%	Very Valid
2.	Media Compatibility	91.6%	Very Valid
3.	Concept Truth	92.4%	Very Valid
4.	Etc	94.4%	Very Valid
	Average Score	**91.4%**	Very Valid

Based on the percentage of data from the validator's assessment results, the material expert validation has a percentage of 91.4% with the category of very feasible material feasibility. Therefore, it can be seen that the development of educational game learning media based on Android is stated to be very valid. However, based on the validation results above, there are several suggestions and comments given by the material expert validator on educational game media which can be seen in Table 6.

Table 6. Criticism and suggestions by material expert validators

No.	Criticism and Suggestions
1	The most important variable of learning media is the correctness of the concept
2	Please check again the synchronization of basic competency numbering with competency achievement indicators so that it is easier to understand
3	In nomenclature material there is no basic information that distinguishes alkanes, akenes and alkynes, namely bonds $-$, $=$, $\equiv$
4	In the matter of differences in organic and inorganic carbon compounds, it is better if the table title also states that what is being discussed is carbon compounds and add an example column to the table to make it clearer.

Criticism and suggestions for improvement from material experts contained in the validation sheet are taken into consideration and the basis for improvement in terms of

material. Improvements aim to reduce errors in the developed educational game media. Based on criticism and suggestions from media expert validators and material experts used for revision so that the media is ready to be used for revision so that the media is ready to be used by students.

Student Readability Test Results

The implementation stage is carried out after the educational game media has been repaired, validated by the validator, and reviewed by the supervisor. Furthermore, the legibility of the educational game media was tested on 33 students of grade 11 at Laboratory High School of Malang to find out the feasibility of the educational game media and then filled out a readability test questionnaire that had been provided by the researcher. The following results of the legibility test of educational game media can be seen in Table 7.

Tabel 7. Student readability test results

No.	Indicator	Percentage	Criteria
1.	Presentation of material	96.6%	Very Valid
3.	Etc	90.6%	Very Valid
	Average Score	**93.6%**	Very Valid

The results of the readability test by students obtained an average of 93.6%. This percentage is included in the very valid criteria. In addition to the assessment data in the form of numbers, there is an assessment of qualitative data in the form of criticisms and suggestions submitted by students. Qualitative data of criticism and suggestions in terms of media and materials can be seen in Table 8.

Tabel 8. Criticism and suggestions for student readability test

No.	Criticism and Suggestions
1	Level 2 has no explanation that answers must be written in capital letters
2	In the game finding hydrocarbons, the image is too small and can't be zoomed
3	The timer isn't long enough, the illustrations could be even more interesting
4	Added corrections wrong and correct question numbers, and added discussion
5	Change the type of backsound song to make it more pleasant to hear
6	Adding other material, especially difficult chapters that have formulas and calculations, the fonts are tidier and more consistent and the colors match

Based on the criticisms and suggestions from the results of the students' readability test, a revision of the educational game media product will be carried out, including providing an explanation at the level of two sub-matter of structure and nomenclature of hydrocarbon compounds, adding a timer, and adding to the discussion of questions.

Effectiveness Test Results

Data analysis of initial abilities (pretest) was carried out to determine initial abilities before implementing learning strategies using educational game media based on Android. While the data on learning outcomes (posttest) is carried out to determine

student learning outcomes after being given treatment. The following is the data from analysis of the effectiveness test of Android-based educational game media for class XI IPA 4 can be seen in Table 9.

Table 9. Effectiveness test results data

Test	$\bar{X}$	Complete	Not Complete	Ngain	Category	Effectiveness Level	Category
Pretest	25	0	34	0.84	Effective	84.6%	Effective
Posttest	88.5	32	2				

Based on Table 9, shows that there was an increase in the scores of students' learning outcomes before and after being given the treatment of learning strategies using educational game media based on Android. This is evidenced by the results of the n-gain score data obtained, which is equal to 0.84 in the high n-gain category and has an effectiveness level of 84.6% in the effective category. Therefore, the use of Android-based educational game media can be applied effectively in improving student learning outcomes in the high effectiveness category. The data diagram of the results of the effectiveness test can be seen in Figure 4.
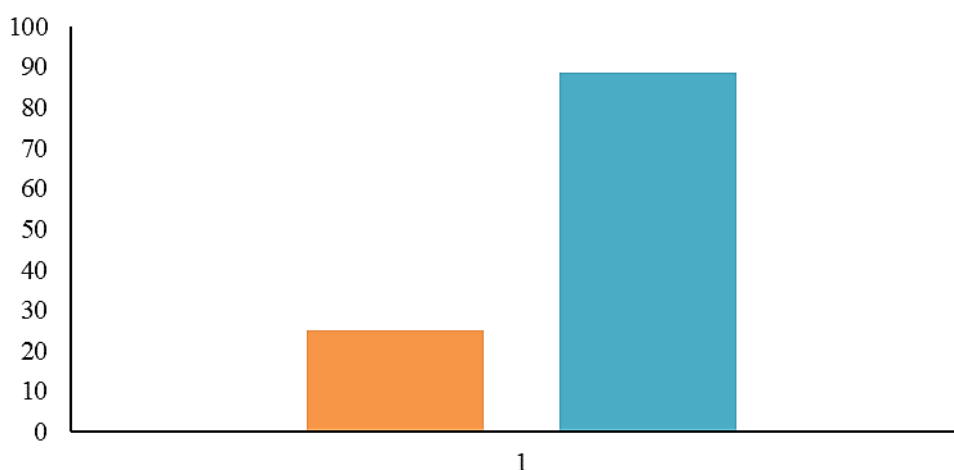
Figure 4. Pretest (light brown) and postest (blue) results

Hydrocarbon educational game development products have been designed according to the stages of the ADDIE development model. This hydrocarbon educational game is equipped with hydrocarbon material, learning videos, practice questions, and educational games with 3 levels. Educational games based on hydrocarbon androids consist of three sub-materials, namely the characteristics of carbon atoms, structure and nomenclature of hydrocarbon compounds, and isomers of hydrocarbon compounds.

Games on the sub-matter of the uniqueness of carbon atoms, the first and second level games use the game method of choosing hydrocarbons and finding hydrocarbons which include material in the form of chains of carbon atoms. Meanwhile, the game at the third level covers the position of carbon atoms in the carbon chain using the drag and drop game method. In the structure and nomenclature of hydrocarbon compounds,

the first and second level games use the crossword puzzle (TTS) method which includes material on homologous series of alkanes, alkenes and alkynes. Meanwhile, the game at the third level covers material for nomenclature of hydrocarbon compounds. In submatter isomers of hydrocarbon compounds, the first and second levels of the game use the choose hydrocarbon game method which includes isomer types of material. While the game on the third level includes material on analyzing isomers of hydrocarbon compounds using the drag and drop game method. At each level of the game, students will immediately know the score from the first level to the third level.

In addition, this game can also train students to focus on working on questions that have been integrated into the game with levels. The higher the level, the more difficult it will be to solve problems in the game to win the game with the highest points. This is in accordance with Heinich's (2002) explanation that games are activities where players must follow different rules from the determined real world and try to achieve challenging goals. At the assessment and analysis stage it is known that students prefer learning using Android-based educational game media because it is easy to carry and learn anywhere and anytime, this is in line with research conducted by Sugiyarto, at al (2018). From the observation results it is also known that all students of high school grade 1I at Laboratory High School of Malang already have smartphones and most of them use. This is in line with research by Fitriyana, et al (2020) that the potential of digital games in the form of educational games as innovative media in teaching science learning, especially chemistry. This educational game media can increase students' attention so as to create a more interactive learning process and a fun learning environment because currently, smartphones not only function as a communication tool, but are also used to play games and study. This has become a game trend among teenagers in competing in learning technology (Nazar at al., 2020).

- **CONCLUSION**

Based on the research on the development of android-based educational game media on hydrocarbon material that has been carried out, it can be concluded that the results of developing android-based educational game media products on hydrocarbon material show that media expert validation is 96.6% (very feasible and very valid), material expert validation of 91.4% (very feasible and very valid), and student readability test results of 93.6% (very feasible and very valid). The N-Gain results show an increase where the pretest data results obtained an average of 25, while the posttest data results obtained an average value of 88.5. From the results of these data, there is an increase in student learning outcomes scores with the N-Gain score obtained at 0.84 in the "high" category and the level of effectiveness in the "effective" category. Therefore, it can be concluded that the android-based educational game media that is applied is effective in improving student learning outcomes. Researchers hope that the results of this game development research can be developed for other game methods that are more innovative, interactive, capable of packaging other chemical content in a representational way and can be used in school learning and can be developed in a web version, not just in the apk format.

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