Developing Educational Game "*Chemistry Virtual Lab*" as Learning Media of Chemical Solution's Concentration Concept for High School Students

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多くの高校生にとって化学の授業は難解だ。記号だらけで数式が多く、抽象的で日常生活との接点がないから興味が湧かない。そこで化学の授業を楽しくするためにゲーム形式の「バーチャル・ラボ（仮想実験室）」を開発し、その効果を検証した。

Abstract

Solution's concentration concept in chemistry subject is an obliged competence that senior high school students should accomplish but the learning and teaching process of solution's concentration concept lacks highly visualized media to increase students' understanding. The conventional method with less attractiveness makes the learning less understandable and hard to be contextually figured out by students. The questionnaires and interview were given at the preliminary research to second grade students and teachers in Senior High School 8 Malang. The findings from this preliminary research showed that 70.4% of the students were not attracted to solution's concentration topic and teachers affirmed the need of the visualized media. This study aims to (1) design an educational game that portrays the real laboratory condition to implement the concept of chemical solution and (2) develop an interesting game in learning and teaching the concept of solution's concentration. This research adapts ADDIE development methodology of *Dick* and *Carry* (1996). This methodology consists of 5 steps as follow: (1) *Analysis*; (2) *Design*; (3) *Development*; (4) *Implementation*; (5) *Evaluation*. Based on the media validation process by using questionnaires, the researcher found that: (1) Media expert's validation score is 87.5%; (2) Subject matter expert's validation score is 85%; (3) small group testing's validation score is 89.58%; and (4) large group testing's validation score is 86.75%. Thus, the developed media can be concluded as valid and highly recommended for use in the learning and teaching process of solution's concentration concept for second grade students of Senior High School.

Keywords Game, Education, Chemistry

Introduction

Chemistry subject is an essential subject in Senior High School mainly for the natural science program. But, the perception that portrays chemistry subject as difficult subject still exist. As suggested by Tiastra, there are four factors that make chemistry subject be perceived as difficult, which are: (1) The syntax of learning model uses boring direct instruction model and Q&A method; (2) There are many formulas and calculation which are abstract and not visualized; (3) The learning and teaching loses relevance to daily basis context and exam-oriented; (4) Less students who continue to the higher education related to chemistry subject that made less attraction in learning it [1].

Based on the fact above, Johari explained that there are seven indications related to the low achievement in chemistry subject learning as follows: (1) incompatible teaching method to the caracteristics of the subject; (2) less motivation given by the teacher to the students; (3) Students only learn chemistry subject at

schools without further exploration to enhance their knowledge related to chemistry subject outside the schools; (4) Low innovation on teaching model and only rely on the old paradigm model; (5) The learning and teaching instrument such as syllabus and study plan are still made in low quality; (6) the sceptism and perception that portray chemistry subject as extremely difficult; (7) and low internal motivation of the students because they think that chemistry subject is less relatable and less significance to their future job [2].

Those problems in chemistry learning and teaching cause the low learning outcome mainly in chemical solution's concentration concept which is still not satisfying. The learning and teaching of chemistry subject must not only be centralized on the result (product) but must also emphasize on the ability to conduct procedural and structural process [3]. In this context, process is defined as an interaction of all learning components in order to achieve the learning goal. The ability to conduct process is an important learning experience that students must feel because the direct involvement of students in applying theory, concept, and fundamental postúlate in chemistry will empower and strengthen the students' understanding about the subject.

The learning and teaching process of chemical solution's concentration concept which include the concept of molarity, molality, and normality of the chemical solution in Senior High School level are still oriented on the solving the questions on paper which only use the techniques that are highly dependent on memorizing the formulas and mathematical operation. In fact, students need direct experience to conduct procedural and systematical process to implement the concept of chemical solution's concentration through making the specific solution with certain amount of concentration. But, there are barriers faced by students of second grade in Senior High School when they must implement the concept by making the spesific solution with certain amount of concentration. Those barriers are: (1) Laboratorium's facilities are not enough; (2) limited amount of chemical materials such as elements and compounds that are going to be made as solute and solvent; (3) the students careles attitude to handle chemical materials.

Developing educational game "CHEMISTRY VIRTUAL LAB" will accomodate students to actively take roles as a lab workers who are given several missions to make chemical solution using specific materials or compounds with certain concentration. Thus, this educational game will be able to subtitute the real laboratorium for the purpose of learning and teaching in chemical solution's concentration concept.

Educational game is highly different with other types of games. Educational game is not only for the entertainment purpose but it emphasizes on increasing the learning interest and motivation of student. Educational game can be used as a useful tool in learning and teaching because game is an interactive multimedia that is highly favoured by students [4]. Henry suggested that the usage of game in the learning and teaching process can optimalize the efficacy of left and right brain simultaneously [5]. The left brain will arrange the strategy regarding what kind of chemical materials that they need to take, how much the volume of the solvent they need, and how the procedure will be. While, the right brain will respond to all the visual information on the monitor screen.

Educational game is acknowledged as a digital learning media. Digital learning media is a learning media that is published by digital devices. This media generally includes text, pictures, audio, and video. Digital learning media has characteristics as follows: (1) utilizing computers' features; (2) utilizing multimedia technologies that are attractive and motivative for students to learn independently; (3) utilizing electronic technologies so that the teachers and students can communicate interactively; (4) using learning materials that is freely accesible to stimulate the thought process and concentration for problem solving [6]. In the learning and teaching process, this game will be an innovative way to facillitate students in gaining impressive and meaningful learning experiences [7].

A good educational game should be able to catch the interest and learning spirit of the students [8]. Therefore, the effort to increase the quality of learning media is an important element to optimize the learning outcome of students mainly in the chemistry subject that contains many abstract concept that doesn't only demand the theoritical ability but also practical ability.

Educational game can be alternative facility that suits with the current learning context where there is shifted paradigm in Indonesia's national education policy. Individual's behavior can be divided into three domains that contain cognitive domain, affective domain, and psychometric domain [9]. Bloom's taxonomy is adapted in the K-13 national curriculum of Indonesia

which now emphasizes on those three domains.

However, in Indonesian Senior High Schools, the learning and teaching of chemical solution's concentration concept, students are less exposed in their psychometric domain. The skill to implement the solution's concentration concept through making the solution with certain amount of concentration is still not optimized because the limited time allocated for the lab practice. The lack of media availability that is supposed to help student to implement the concept by trying to make the chemical solution's concentration concept causes the psychometric acquisition process less effective. By this research, the availability of interesting media that can give meaningful learning experience and intensive exposure on conducting chemistry procedural process for students to implement the chemical solution's concentration concept will be optimized.

Research Method

This research adapts the R&D research model. This model is used to create certain products and test its effectiveness [10]. Based on the potential problem faced by the researcher, ADDIE development model of *Dick and Carey* (1996) is the most suitable model to address the problem [11]. The basic concept of ADDIE development model can be explained by the scheme in Fig. 1.

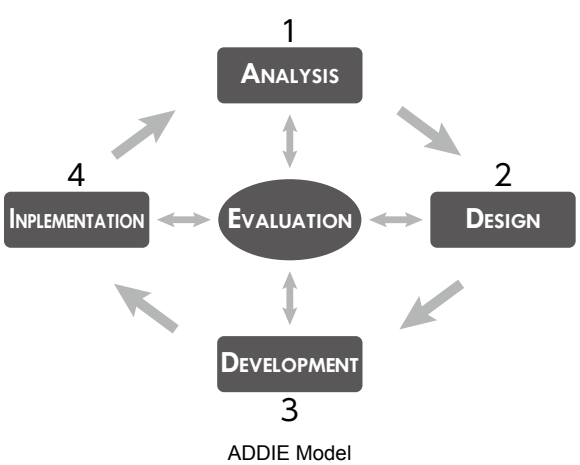

Fig. 1. ADDIE development model.
(Source: Dick & Carey, 1996)

Analysis

In this stage, the researcher conducted preliminary research to find out the potential problema and the necessity analysis. This preliminary research was done by using questionaire and conducting interview in SMAN 8 Malang. The questionaire was given to 125 second grade students of SMAN 8 Malang to find out their learning motivation, learning interest, and their perception upon chemical solution's concentration concept. From this questionaire, the reseacher concluded that 70.4% of the students were not attracted to solution's concentration topic. The interview was conduted to the teacher of chemistry subject to find out their necessity for learning media in solution's concentration topic. From the interview, the researcher found out that the teachers needed visualized media to facilitate the learning and teaching of solution's concentration concept. Therefore, there is an urgency for the researcher to develop learning media for solution's concentration topic.

Design

In this stage, the researcher designed the game arrangement process, game layout, laboratory's components, mission, game instruction, cover, and manual book and module.

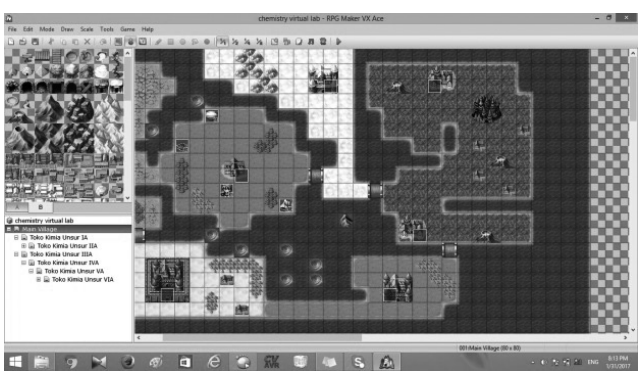

Fig. 2 Game's main map design.

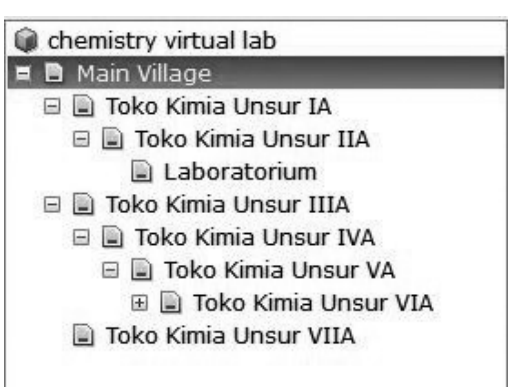

Fig. 3. Game's building list design.

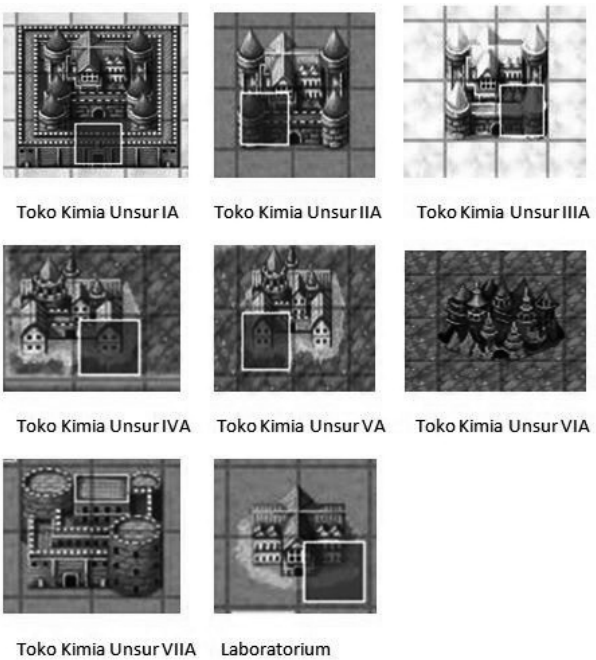

Fig. 4. Chemical material stores and laboratory

Development

In this stage, the researcher will realize the designs that have been made before. There are two main focuses in this stage which are realization of game and realization of module and manual book. In the realization of game, the researcher arranged the algorithm for game program and creating the animation characters which involve in the game. In the realization of module and manual book, the researcher arranged the guidance for the missions in the game and the task the students have to do systematically.

Implementation

In this stage, the products in the form of game, module, and manual book will be tested to the research's subjects. The subjects of this research are one media expertise, one material expertise, 12 students for small group testing, and 125 students for large group testing

The data collection instrument that is used in this research is questionaire with Likert's scale. The collected data are qualitative and quantitative data. The data analysis technique is descriptive-quantitative technique.

Evaluation

In ADDIE development model, evaluation process is conducted in every stage started from analysis, design, and implementation. The revisión is done in every stage to make sure that the design and product are valid. The revisión is gotten from the suggestion and recommendation of media and material expertises.

Result and Discussion

There are five results that the researcher found. They are the preliminary research result, validation result from media expertise, validation result from subject matter expertise, result of small group testing, and result of large group testing.

Preliminary Research Result

As mentioned in the analysis section, the R&D research should firstly identify the potential problem and necessity for development. In order to identify the potential problem, the researcher has conducted the preliminary research by using questionnaire to 125 second grade students of SMAN 8 Malang. The collected data from this questionaire is analyzed by using descriptive statistic method in IBM SPSS Statistics 21. The result of preliminary research is summarized in Table 1.

Table 1. Descriptive Statistic from Likert Questionnaire

Scale	f	%	CF
1	35	28%	28%
2	53	42.4%	70.4%
3	23	18.4%	88.8%
4	14	11.2%	100%

From Table 1, we can see that the there are 29.6% (37 students) of second grade students in SMAN 8 Malang who are interested in solution's concentration topic because they fill the questionaire with 3 and 4 that indicate their interest in the topic. However, the rest 70.4% (88 students) of them are not interested in the topic. Based on the criteria proposed by Arikunto [12], the criteria of score can be seen in Table 2.

Table 2. Arikunto's Likert Criteria

Value (%)	Criteria
81-100	Very High
61-80	High
41-60	Medium
21-40	Low
0-20	Very Low

From the criteria in Table 2 proposed by Arikunto, the interest of second grade students in chemical solution's concentration topic is low. This result can be visualized by Fig. 5.

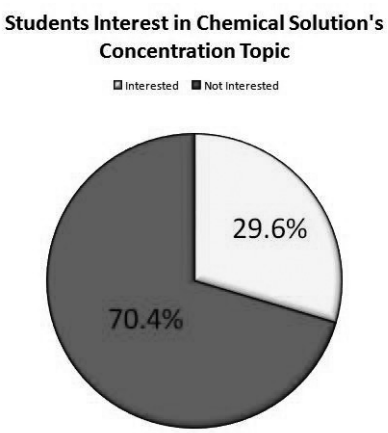

Fig. 5. Diagram of students' interest from preliminary research

Media Expertise's Validation Result

The method to collect data of validation from media expertise is by using the questionnaire. The media expertise that validated "CHEMISTRY VIRTUAL LAB" educational game is Drs. Dwi Prihanto, S.T, M.T. There are 30 items as indicators in the questionaire to find out the validity of media. All 30 items were filled out by the media expertise with Likert scale (1-4). The validity of media will be calculated by the formula as suggested by Akbar [13].

$$V = \frac{TSe}{TSh} x100\%$$

V = Validity

Tse = total score from expertise

TSh = Maximum score

The result of media expertise's validation can be seen in Fig. 6. and Fig. 7.

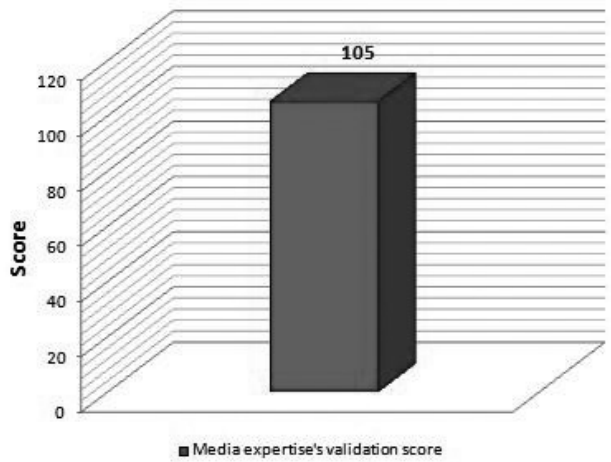

Fig. 6. Media Expertise's Validation Score

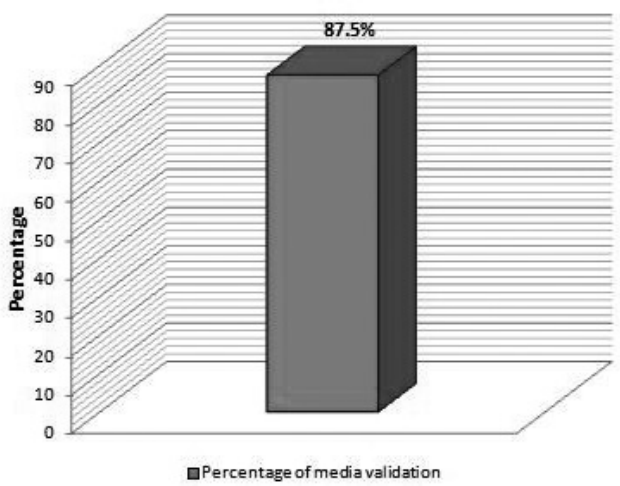

Fig. 7. Percentage of Media Validation

From Fig. 7 the validation percentage is 87.5%. According to Akbar (2013) the criteria of validity can be seen in Table 3 [14].

Table 3. Validity Criteria

Value (%)	Criteria
81.26-100,00	Very Valid Without Revision
62.51-81.25	Valid with revision
43.76-62,50	Not Valid
25.00-43.75	Very not valid and musn't be used
81.26-100,00	Very Valid Without Revision

Based on Table 3, the percentage of validation for "CHEMISTRY VIRTUAL LAB" educational game from media expertise is very valid without revision because the validity percentage is 87.5%.

Material Expertise's Validation Result

The method to collect data of validation from material expertise is by using the questionaire. The media expertise that validated "CHEMISTRY VIRTUAL LAB" educational game is Vinda Paramitha, S.Pd who is the teacher of chemistry subject in Senior High School. There are 30 items as indicators in the questionaire to find out the validity of media. All 30 items were filled out by the material expertise with Likert scale (1-4). The validity of media will be calculated by the formula as suggested by Akbar (2013).

The result of material expertise's validation can be seen in Fig. 8. and Fig. 9.

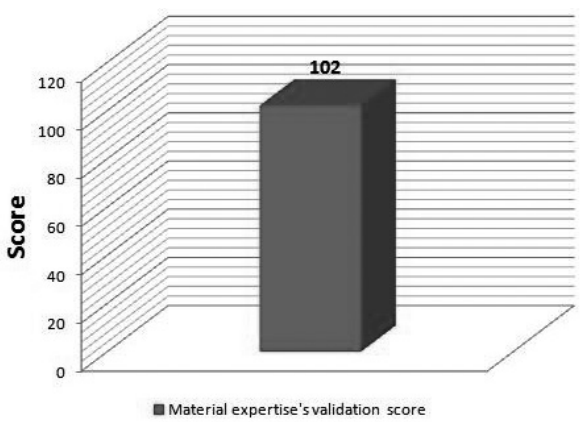

Fig. 8. Material Expertise's Validation Score

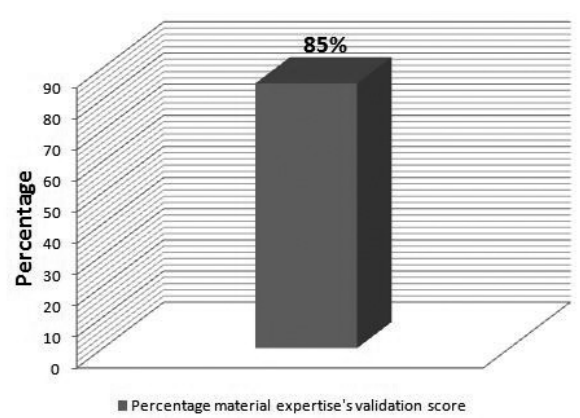

Fig. 9. Percentage of Material Validation

From Fig. 9, the validation percentage is 85%. According to the criteria of validity in the table 3, validity of "CHEMISTRY VIRTUAL LAB" educational game from media expertise is very valid without revisión because the validity percentage is 85%.

Small Group Testing Result

The method to collect data of validation from small group testing involves 12 second grade students of SMAN 8 Malang by using the questionaire. There are 15 items in the questionaire with Likert scale (1-4). The obtained score from this small group testing is 645 and the máximum score is 720 which means that the percentage of validity from this small group testing is 89.58%. The result of small group testing can be seen in Fig. 10 and Fig. 11.

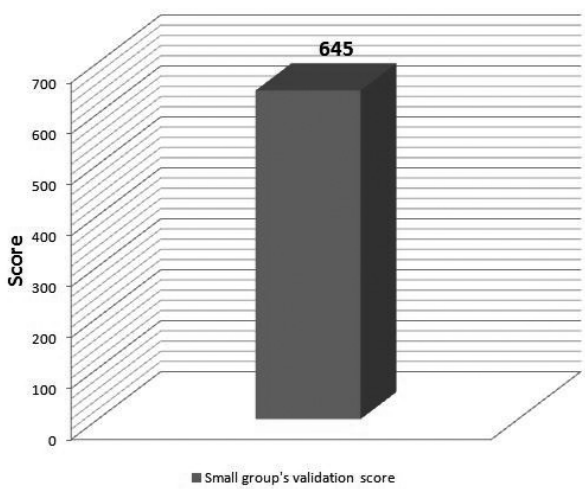

Fig. 10. Small Group Testing's Validation Score

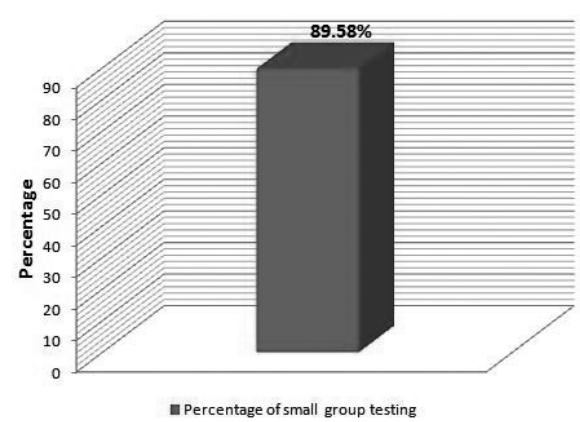

Fig. 11. Percentage of Small Group's Validation

From Fig. 11 the validation percentage is 89.58%. According to the criteria of validity in Table 3, validity of "CHEMISTRY VIRTUAL LAB" educational game from small group test is very valid without revisión because the validity percentage is 89.58%.

Large Group Testing Result

The method to collect data of validation from large group testing involves 125 second grade students of SMAN 8 Malang by using questionaire. There are 16 items in the questionaire with Likert scale (1-4). The obtained score from this small group testing is 6940 and the máximum score is 8000 which means that the percentage of validity from this large group testing is 86.75%. The result of small group testing can be seen in Fig. 12 and Fig. 13.

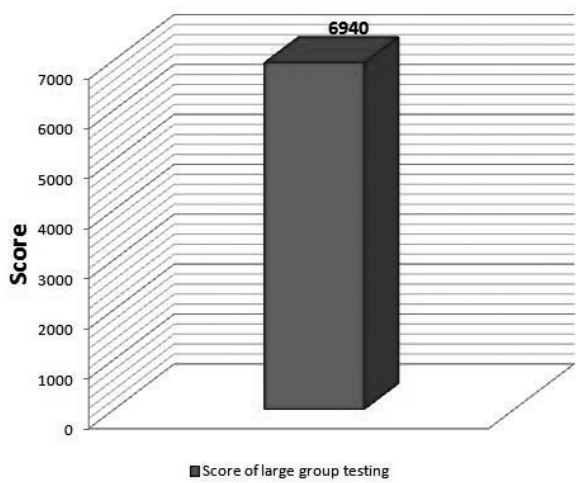

Fig. 12. Large Group Testing's Validation Score

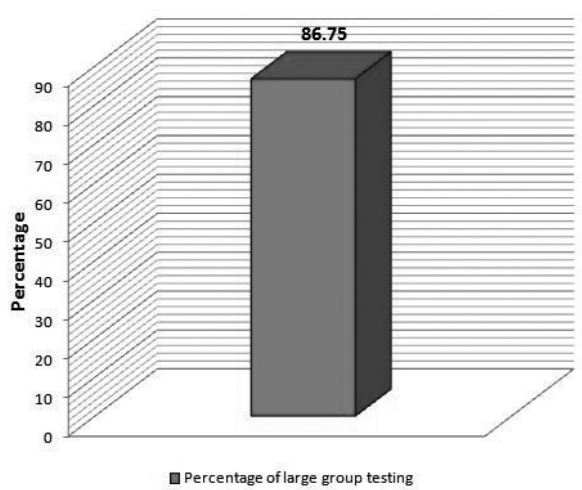

Fig. 13. Percentage of Large Group's Validation

From Fig. 13 the validation percentage is 86.75%. According to the criteria of validity in Table 3, validity of "CHEMISTRY VIRTUAL LAB" educational game from small group test is very valid without revisión because the validity percentage is 86.75%.

Conclusion

From the discussion above, the researcher can conclude that educational game "CHEMISTRY VIRTUAL LAB" is valid and highly recommended for use in learning and teaching of chemical solution's concentration concept for second grade students of Senior High School. The developed media can be categorized as valid due to several validation processes that have been conducted. The validation processes are media expert validation (87.5%), material expert validation (85%), small group testing validation (89.58%), and large group testing validation (86.75%).

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