Educational Media Development using Guided Discovery Learning Approach in Chemical Element Subject

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Abstract. A chemical element is one of the materials in high school for chemistry subject. Students have difficulties in studying chemical elements due to ample theories that must be memorized. In addition, conventional learning models that tend to be one-way create boredom feeling towards students. The use of interactive educational media can be a solution to the learning process. This study tries to provide a solution by developing mobile-based educational media combined with guided discovery learning models to help the learning process of chemical elements in high school. The use of appropriate educational media can be used as an independent learning tool. This study uses Research & Development (R&D) combined with SAM Model to develop this educational media. Testing is using an expert validation approach for the prototype of educational media. This study adapted the Computer System Usability Questionnaire (CSUQ) to assess an aspect of the usability of educational media. To assess the content of the material in this educational media, this study uses an evaluation questionnaire from the subject matter and media experts. The development process is carried out in three iterations, namely the preparation stage, iterative stage, and iterative development stage. The results of this study show that the assessment of chemical elements in educational media has a score of 86.8% on its system usability according to media experts and a score of 90.5% on educational media content according to material experts. So, this educational media is feasible to be applied to high school students. Overall, this educational media got a good score on the pretest-posttest, where the effectiveness of using this educational media increased student learning outcomes with an N-Gain value of 80.62%.

Keywords: educational media, chemical element, guided discovery learning

1 Introduction

Chemistry is a subject that is less attractive to students due to its abstract and complex nature [1], [2]. One of the materials in high school is a chemical element. The chemical element subject is dominated by theories so it requires students to memorize chemical properties, physical properties, abundance, purification, manufacture, and important reactions in a group or period. Based on the results of observations with the chemistry teacher, students got less than optimal scores on this material. This is because there is a lot of material to be studied while the time available is limited. The learning
model carried out by the teacher is through discussion, presentation, and lecture. This method tends to be one-way and does not develop an understanding of the topics presented [3]. Also, this method causes students to feel bored and less effective [4]. The challenge in education is to develop a learning process to increase students' understanding of the material that must be learned. The learning model must be able to make students participate in teaching and learning activities thoroughly in a comfortable atmosphere, hence, enhancing the effectiveness of ongoing learning. Based on the syntax of each learning model, guided discovery learning is one of the appropriate learning models in the application of elemental chemistry material because it involves students directly in searching, studying and analyzing so that they can get information about the material with his own [5]. This learning model was developed to reduce misconceptions that are not organized in a guided manner [6].

Technology improvement, especially mobile-based, has been widely developed in the field of education, and this has a significant impact on the learning process in schools [1]. Educational media usage can increase students' enjoyment during the learning process [7]. The advantage of visualization in the media can reduce the level of abstraction and complexity of the concept. So, it can be concluded, that the use of media has a positive effect compared to conventional methods [2] in terms of improving learning outcomes [8] and students' learning motivation [9]. The appropriate learning media can be used as an independent learning tool.

Learning innovation can facilitate the learning process optimally, more effectively, and efficiently [10]. Integrating educational media and learning models can be a solution to existing problems. Several studies expanded the educational media on chemical materials such as chemical bonds [11]–[13], chemical reactions [14], [15], salt solubility [2], and atomic structure [16]. However, no research specifically develops educational media on a chemical element by combining guided discovery learning models.

Based on the problem that has been described, this study proposes the design of an effective mobile-based educational media as a medium for learning chemical elements. The expected result is that with this educational media, students will more easily understand the concept of chemical elements. This study focuses on discussing solutions to problems that have been described previously in the form of educational media design based on the development and testing that has been proposed.

2 Theoretical Background

2.1 Educational Media

Educational media is media designed to educate or enlighten knowledge [17] to support the learning process to achieve its goals [18]. Educational media is a visual aid to help to convey abstract material. The media can be in the form of sound, images, videos, or combined animations [18]. There have been many educational media technologies used in the teaching and learning process, such as digital games and computer systems. The existence of varied educational media will make students more interested and eager to learn, as to improve student learning outcomes [19]. Another advantage gained from the application of educational media is to save time and minimize misconceptions in the delivery of material [18].

2.2 Chemical Element

The chemical element is a subject for senior year (Grade 12) in Odd Semester. The main topics of discussion include elemental abundance, elemental properties, the
usefulness of elements and compounds, and the determination of the substance contained in the product [20]. This material contains conceptual, contextual, and descriptive theories that are popular among students with the term rote material. More than 100 chemical elements have been known and identified. Each element has its characteristics. These elements are generally found in nature, although some elements are artificial. Since many chemical elements exist in nature, the elements are grouped according to the increase of their atomic number and their similar properties in the periodic system of elements. The elemental properties are divided into atomic properties, physical properties, and chemical properties. Atomic properties include electron configuration, atomic radius, ionization energy, electron affinity, electronegativity, and oxidation state/oxidation potential for atoms. Physical properties include appearance, color, odor, density, hardness, melting point, boiling point, thermal and electrical conductivity. Chemical properties include reactivity, reduction power and oxidation, and acidity.

2.3 Guided Discovery Learning

According to Bruner, discovery learning is a learning model that uses inquiry-based learning theory that occurs in the problem-solving process [6]. This model motivates students to be more active and helps them to get an in-depth understanding of the concept [21]. This is in line with Sugiyono's suggestion in [22] that the guided discovery model is one of the learning models in which students gain knowledge through questions, demonstrations, or other media. Guided discovery learning creates a learning atmosphere by involving students actively and independently [23]. The guidance provided by the teacher is limited because it will be similar to direct learning if the teacher guides too much [6].

There are several procedures carried out in the application of guided discovery learning [24], namely: (1) Stimulation that aims to generate students' desire to explore, (2) Problem statements to build students' thinking patterns in finding a problem, (3) Data collection purposes to collect as much relevant information as possible, (4) Data processing to get conclusions based on the information acquired, (5) Verification to prove whether the material is correct or not and (6) Generalization to conclude understanding one material or problem.

3 Methodology

As explained in the introduction, two problem formulations were formulated, namely (1) what is the form of mobile-based chemical element educational media design with a guided discovery learning approach?, (2) how are the results of the development of chemical element educational media in the perspective of media experts and subject-matter experts quantitatively? and (3) how is the usefulness value of the chemical element educational media on students' perception?

Generally, this research used the Research and Development (R&D) method where this research method served to test, improve, and make certain products. The R&D method has four levels, this research was included in the highest level because it created new products that had never existed before [25]. To get a tested product, it is necessary to validate each stage. The validation was executed by experts to ensure the design and development of educational media are appropriate and feasible to use [26]. Some media experts are practitioners in the field of media development for at least five years and material experts are teachers of chemistry subjects in high school. In practice, this research combined the Successive Approximation Model (SAM) software development method for the process of creating educational media. The flow of this
Research methodology can be seen in Fig. 1.

**Fig. 1. Research Methodology**

### 4 Result and Discussion

#### 4.1 Preparation Phase

This stage was the earliest in the design and development process. This stage aimed to dig up information about the needs in the development of educational media. Information gathering was done by interviewing material experts. Based on the information obtained, then an initial discussion with the team regarding the initial design of educational media was carried out. The initial design included the explained materials, the concept of educational media, the application of the guided discovery learning model, and the basic interface of the educational media. The result of this stage is a needs analysis in the form of a use case diagram. This chemical element education media has only one actor, namely high school students majoring in sciences. The use case diagram of the proposed elemental chemistry education media is shown in Fig. 2.

**Fig. 2. Use case diagram**
The first use case is doing the pretest. In accordance with the application of guided discovery learning, the actor works on the pretest questions first to find out knowledge about the material being learned. The second use case is looking at pretest scores, the third use case is learning material, the fourth use case is doing practice questions, the fifth use case is conducting experiments, the sixth use case is working on the final quiz and the last use case seventh is seeing the final quiz score.

4.2 Iterative Design

The concept of educational media, in general, was the application of guided discovery learning in the learning flow of this educational media. Guided discovery learning has six steps, namely stimulus, problem statement, data collection, data processing, verification, and generalization [6]. The initial design was performed based on the analysis of user needs in the previous stage which was described as a rough sketch of the flow of the educational media. Then the results of the sketch were improved in quality into a wireframe that shows the layout of the navigation, functional specifications, and notes in every function. This wireframe design was then tested by media experts and material experts using the A/B testing method. The wireframe design can be seen in Fig. 3 for wireframe design A and Fig. 4 for wireframe design B. The testing process was finalized by voting on the proposed design options. After the A/B testing process has been carried out, it can be seen in Fig. 5 showing that the subject-matter and media expert chose design B with a value of 75%. The A/B testing process is carried out 1 time because the final value reaches 75%.

Fig. 3 Wireframe Design A

Fig. 4 Wireframe Design B
The results of the A/B testing were developed into mock-ups that emphasized more on aesthetic design. This aesthetic design included a choice of colors. Color determination was carried out according to the theory of “analog” harmonic color combinations, namely by combining two or more adjacent colors in the color circle [27], [28]. The mock-up of this educational media can be seen in Fig. 6. The results of the mock-up were tested again by media experts for color selection. The result of A/B testing was that media experts choose the dominant color of blue which expresses truth, strength, and coolness [28].

4.3 Iterative Development

After the design process was complete, the next step was the development process where there were two iterations of media and material validation so that
educational media could be distributed to users. To obtain validation on the process of developing the media is done with a questionnaire. The questionnaire used was adapted from Lewis [29] and Wahono [30] for media and material expert validation.

4.3.1 Media Expert Validation

The measurable test results obtained in the first iteration by media experts can be seen in Table 1. These results show an average of 64% on the software aspect, 62% on visual communication aspects, 61% on media design aspects, and usability aspects of 68%. The total average acquired is 63.75%. The assessment still does not meet the standard value in the R&D method, which is 75%.

Table 1. First Iteration Media Expert Validation

<table>
<thead>
<tr>
<th>Expert</th>
<th>Aspect</th>
<th>Value (0-100)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Media</td>
<td>Software Engineering</td>
<td>64</td>
</tr>
<tr>
<td>Media</td>
<td>Visual Communication</td>
<td>62</td>
</tr>
<tr>
<td>Media</td>
<td>Media Design</td>
<td>61</td>
</tr>
<tr>
<td>Media</td>
<td>Usability</td>
<td>68</td>
</tr>
<tr>
<td>Average</td>
<td></td>
<td>63.75</td>
</tr>
</tbody>
</table>

After making improvements according to media expert suggestions, the results of the assessment in the second iteration can be seen in Table 2. The results acquired are 92% for software engineering aspects, 88% for visual communication aspects, 86% for media design aspects, and 81.5% for usability aspects. The total average obtained is 86.8%. An escalation of 23% from the previous iteration process.

Table 2. Second Iteration Media Expert Validation

<table>
<thead>
<tr>
<th>Expert</th>
<th>Aspect</th>
<th>Value (0-100)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Media</td>
<td>Software Engineering</td>
<td>92</td>
</tr>
<tr>
<td>Media</td>
<td>Visual Communication</td>
<td>88</td>
</tr>
<tr>
<td>Media</td>
<td>Media Design</td>
<td>86</td>
</tr>
<tr>
<td>Media</td>
<td>Usability</td>
<td>81.5</td>
</tr>
<tr>
<td>Average</td>
<td></td>
<td>86.8</td>
</tr>
</tbody>
</table>

4.3.2 Subject-Matter Expert Validation

In addition, in terms of the usefulness of the media, it is necessary to validate the content of the material that has been contained in the educational media. This is done so there is no deviation from the subject matter in the applied curriculum. The results of the subject-matter expert's assessment can be seen in Table 3. The material assessment for the content of the educational media was carried out twice with an average result in iteration 1 of 74% and an increase to 90.5% in iteration 2. In accordance with the assessment standards of the R&D method, the results in iteration 2 can be implemented for end-users.

Table 3. Subject-Matter Expert Validation

<table>
<thead>
<tr>
<th>Iteration</th>
<th>Aspect</th>
<th>Value (0-100)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Iteration-1</td>
<td>Material Aspect</td>
<td>74</td>
</tr>
<tr>
<td>Iteration-2</td>
<td>Material Aspect</td>
<td>90.5</td>
</tr>
</tbody>
</table>

4.3.3 The Result of Development

Based on the assessments and decisions of the validation of media and subject-
matter experts in the last validation iteration, the results of the development of educational media used for this study can be seen in Figures 7 to 11.

Fig. 7 Main Page

Fig. 7 shows the main page when the user opens the chemical elements education media. The main page contains 3 menu buttons namely start, instructions, and settings. The start button functions to start working on the pretest, the instructions button opens the instruction page for using educational media. The setting button is used to adjust the sound for educational media.

Fig. 8 Understanding Test Page

Then go to the next page, namely the understanding test page which is part of the stimulation in guided discovery learning. Users have to work on several questions before starting to learn the theory of chemical elements. The display of the understanding test can be seen in Fig. 8, the questions that must be answered by the user are 16 questions. These questions have been validated by subject-matter experts.
They can see the value obtained and the number of questions that were successfully and unsuccessfully answered, as shown in Fig. 9.

![Fig. 9 Feedback Page](image)

This educational media provides four choices of material that can be selected by the user. On the material page, there are different positions of the buttons according to the advice of media experts in the design iteration process. The final result of the position of the buttons used can be seen in Fig. 10. The application of the problem statement, data processing, and data collection steps is illustrated at the learning stage in this educational media where users can find all information about the chemical elements in this application. The solution given to this educational media is a virtual experimental simulation using animation as shown in Fig. 11 which is an illustration of the flame color test and the reactivity test. In the experimental simulation, the user can drag and drop so that the learning media is more interactive.

![Fig. 10 Material Page](image)
4.4 Experimental Test

After the development process has been completed, the next step is to conduct experiments on the end user. This study used a quasi-experimental study design with the Nonequivalent Control Group Design where the research group was divided into two groups with different treatments. Both groups will be given a pretest and posttest using the same questions. Participants in the experimental group will use chemical elements education media with a guided discovery learning approach as a student learning tool. While the control group was given treatment with a conventional approach.

The experimental process in this study was carried out in grade XI senior high school students with a total of 40 students participating as respondents. The 40 students were divided into two equal groups, namely 20 students for the control group and 20 students for the experimental group. Data collection was carried out in 2 sessions online or online because circumstances did not allow it to be done face to face.

To determine the effectiveness of using a particular treatment in quasi-experimental research, it is necessary to calculate the normalized gain score (N-Gain score). To get the N-Gain score, we do it by calculating the difference between the pretest and posttest values as in equation 1. The N-Gain value assessment category can be determined based on the N-Gain value in percent (%). The distribution of N-Gain values [31] can be seen in Table 4.

\[
\text{Normalized Gain (N - Gain)} = \frac{\text{Posttest score} - \text{Pretest score}}{\text{Maximum score} - \text{Pretest score}}
\]  

(1)

<table>
<thead>
<tr>
<th>N-Gain Score (g)</th>
<th>Category</th>
</tr>
</thead>
<tbody>
<tr>
<td>g &gt; 70%</td>
<td>High</td>
</tr>
<tr>
<td>30% &lt; g ≤ 70%</td>
<td>Medium</td>
</tr>
<tr>
<td>g ≤ 30%</td>
<td>Low</td>
</tr>
</tbody>
</table>

After the experimental process was completed, data analysis was carried out based on the posttest and pretest values of the two groups to obtain the N-Gain score. The N-Gain score of the two groups can be seen in Table 5.
Based on Table 5 shows that the average N-gain score in the experimental group is 80.6272 or 81% included in the "high" category. With a minimum N-gain score of 60% and a maximum of 100%. Meanwhile, the average N-gain score in the control group was 58.0601, or 58% included in the "medium" category. With a minimum N-gain score of 33.33% and a maximum of 91.67%. Thus, it can be concluded that both groups experienced an increase in learning outcomes even with different treatments. However, the use of chemical elements in educational media has higher effectiveness compared to conventional treatment.

4.5 Usability Testing

Usability testing is utilized to determine the value of system usability according to end-users. In this study, the research instrument CSUQ (Computer System Usability Questionnaire) is divided into several aspects, namely system usability, information quality, and interface quality [29]. The system usability aspect is found in questions 1 to 6 which aim to assess the suitability of the use of educational media to the user requirement. Furthermore, questions 7 to 12 are an assessment of the quality of information and these questions aim to assess the quality of content or material presented in educational media. The next aspect is the quality of the interface contained in the last four questions where the question aims to determine the quality of the interface of educational media in the form of an attractive appearance and ease of operation.

Research instruments are given to end-users who have thoroughly interacted with educational media. From the three categories, the results can be seen in Table 6 that the average value of the system usability aspect, information quality, and interface
quality, respectively are 89.5%, 91%, and 89%.

<table>
<thead>
<tr>
<th>Aspect</th>
<th>Average</th>
<th>Value (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Usability</td>
<td>4.475</td>
<td>89.5</td>
</tr>
<tr>
<td>Information Quality</td>
<td>4.56</td>
<td>91</td>
</tr>
<tr>
<td>Interface Quality</td>
<td>4.45</td>
<td>89</td>
</tr>
<tr>
<td>Overall</td>
<td>4.495</td>
<td>90</td>
</tr>
</tbody>
</table>

5 Conclusion and Future Work

This study describes the process of designing and developing educational media which is then analyzed for the use of the system and tested for the effectiveness of the application on student learning outcomes. The design of educational media on elemental chemistry material applies a guided discovery learning approach and succeeds in getting good grades and is suitable for use by high school students. In the development process, it uses a material expert and media expert validation test approach. The results of the material expert test obtained a score of 90.5% on the aspects of the material presented. Meanwhile, the media expert test scored 92% on the software engineering aspect, 88% on the visual communication aspect, 86% on the media design aspect, and 80.5% on the usability aspect.

In addition, this study conducted experiments on two groups with different treatments to determine the effectiveness of the approach that has been taken in improving learning outcomes. The results of these experiments are conventional learning and the use of educational media both improve student learning outcomes. However, the effectiveness of using learning media is higher (80.62%) than conventional learning (58%). So it can be concluded that the use of chemical elements learning media is effective for use by high school students to understand chemistry subject. Based on the results of this study, further research can be carried out regarding the usability of this educational media so that users are more comfortable in using it, considering that the value on the usability aspect is the lowest, besides that it can also deepen the material presented. Media development can be developed on iOS devices because currently it can only be utilized on Android.

References

84

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