Development of chemistry e-module flip pages based on chemistry triplet representation and unity of sciences for online learning

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Abstract. The digital module can be used as a solution in online learning during the Covid-19 pandemic. The purpose of this study was to develop and evaluate a Chemistry e-Module Based On Chemistry Triplet Representation and Unity of Sciences. Research and development were conduct to developed this e-module. The steps were: (1) research and information collected; (2) planned; (3) developed a primary form of product; (4) preliminary field-tested; (5) main product revision; (6) main field-tested; (7) operational product revision; (8) operational field-tested; (9) final product revision; (10) dissemination and implementation. Pre-test post-test control group design was applied to see the effectiveness of e-Module on critical thinking skills. Data were collected using test and non-test methods. The research subjects were students of the Chemistry Education Department, UIN Walisongo. Chemists and multi media experts have done the validation to test the initial quality of the products and give a feedback for the product improvement. The results of the validation test from experts reviews obtained a mean score of 3.85 from a maximum score of 4, which indicated that the e-Module was in the Eligible category. The media expert’s assessment got a mean score of 4.0 from a maximum score of 5 which means that the e-module was in the Appropriate category in media aspects. The e-Module got a mean score of 3.64 from the highest score of 4, which means that the e-module developed was in the very feasible category according to students. T-test results showed that there were differences in N-gain score between control and experimental group. It has been proved to be significantly different (sign test from SPSS showed < 0.05), with the mean score of the experimental class being higher than the control class. The Control group achieved an N-gain score of 0.53 (moderate category) otherwise experimental group achieved 0.80 (high category) which was higher than the control group.

Keywords: e-module, triplet representation, unity of sciences

1. Introduction

Unity of Sciences has an important role in overcoming the character crisis which is the main factor of moral problems, which comes from a spiritual crisis [1]. Indeed, knowledge should deliver to closeness to Allah SWT. As a chemistry educator candidate, UIN Walisongo chemistry education students are expected to be professionals in the knowledge of chemistry and have a foundation of
relating to how to return the estuary of the river and changes it undergoes is critical thinking. Students need visualization tools to understand these three levels of representation, which includes macroscopic, microscopic, and symbolic language. An approach that is able to integrate the three levels of chemical representation is needed to form a comprehensive understanding. The low ability of students in understanding chemistry is associated with the lack of developed sub-microscopic representations through proper visualization of chemistry learning. The sub-microscopic level is a difficult part to develop because of its abstract and invisible characteristics, so teachers need tools to help visualize this level. Unfortunately, there is a gap between the three levels which causes difficulties for students to study chemistry.

Chemistry contains abstract concepts that have the potential to cause difficulties for students if they are only presented using text/graphic components such as those that have been widely used in teaching materials in general. Another cause of the difficulty of students in studying chemistry is the gap between the real-life of students and what is taught in chemistry classes. Students every day come into contact with real-world phenomena through their five senses, but when in chemistry class, chemistry teachers usually explain chemical concepts at a symbolic level such as atoms and formulas, as a result, many students find it difficult to learn chemistry. This leads to the assumption of students that chemistry subjects contain formulas and symbols that must be memorized; this is evidenced by the results of pre-research questionnaire which shows that 60% of early-level chemistry educators think that chemistry subjects are dominant in memorizing formulas and symbols. This of course has an impact on the less developed thinking skills of students. In fact, critical thinking skills are one of the skills needed in the 21st century.

Many students also experience misconceptions in learning chemistry, especially the problem of acid-base which is an essential topic to support understanding advanced topics such as materials chemistry, organic chemistry, and biochemistry. This can be seen from the findings in the field which show that 40% of students have not been able to connect the three levels of representation when asked questions regarding the location of electrons in covalent bonds. Most students do not pay attention to the aspect of the autoionization reaction of water when representing an acid or base solution, when traced through interviews, students find it difficult to obtain a complete picture on the submicroscopic scale due to the absence of independent teaching materials that can help them obtain submicroscopic molecular images in three dimensions. These findings are commensurate with the statements of stated that the main problem of difficulties in learning chemistry is the disconnection of the macroscopic, submicroscopic, and symbolic levels or often referred to as chemistry triplet representation. This is because the characteristics of chemistry are studying an abstract concept that cannot be observed in real terms, such as interactions between atoms, molecular structures, electron clouds, etc. all three levels.

So far, the teaching materials used in secondary schools still only focus on the aspects of memorizing symbols and formulas, without being linked to solving relevant problems in their environment. This causes critical thinking skills to be underdeveloped, whereas the ability to get a full picture of these three levels is linear with increasing critical thinking skills. To get a comprehensive picture of these three levels of representation, students need visualization tools that involve moving animation complemented by visuals. This makes the development of a learning...
resource for students that are able to connect the three urgent chemical representation levels to be met immediately. Based on the background that has been described, the objectives of this study are (a) Knowing the feasibility of the e-Module according to the expert; (b) Determining the effectiveness of e-Module students' critical thinking skills; (c) Knowing student responses to e-Modules.

2. Method
This type of research was research and development (R&D). This research aimed to produce an e-module on the topic of acid-base. The research and development stages are adopted from Gall, Gall, & Borg (2007: 570). The steps were: (1) research and information collected; (2) planned; (3) developed a primary form of product; (4) preliminary field-tested; (5) main product revision; (6) main field-test; (7) operational product revision; (8) operational field-test; (9) final product revision; (10) dissemination and implementation. The data collection instruments used in this study included test and non-test instruments. Critical Thinking skills test with essay types that aim to investigated students' critical thinking skills [19]. The non-test instruments used were questionnaires, interviews, and field notes.

The research began with conducting a needs assessment, which includes literature study and field studies. Based on the needs analysis in the previous stage, the next step was the planning step, which is followed by starting to create an outline and segments that will be displayed in the e-module. The e-module prototype then consulted with experts for formative evaluation. This activity could be carried out in parallel in the form of an expert review activity simultaneously with a one to one evaluation activity [20]. Expert Reviews activities were conducted to obtain information from an expert perspective. Chemists and multimedia experts have validated to assess the initial quality of the products and give feedback for product improvement.

One to one activity was carried out by visiting one student at a time to get input from the student's perspective as a user of e-module products. The next stage was to make e-Module improvements based on input from experts and also from students. After the revision was carried out based on the results of the initial phase of testing, the next step was to conduct trials in small classes. A small trial was carried out involving 15 students. The next step was to repair the e-Module again. Furthermore step was to conduct a field test using an experimental pre-test post-test control group design to test the hypothesis whether the e-module that has developed was effective in improving critical thinking skills. The last stage was to disseminated e-module products.

3. Results and Discussion
The e-module development begun with a need assessment. One of the need assessment activities was carried out by distributing questionnaires to students majoring in chemistry education in the first semester, totaling 75 prospective teacher students. The results of the preliminary study have found several problems, one of which is that most students have difficulty connecting the three levels of representation in chemistry. An open questionnaire related to the initial perceptions of first semester students also showed that 60% of early-level chemistry educators think that chemistry subjects are dominant in memorizing formulas and symbols, even though to understand the concept of chemistry as a whole, it requires an understanding of the three levels of representation, namely the macroscopic, submicroscopic level, and symbolic language [21]. The exploration of student concepts was carried out using cognitive conflict strategies, by providing several questions. This misconception was reflected in the following statement "as the pH increases, an acid becomes less and less harmful, and the higher the H + concentration, the higher the acid strength". The findings of this misconception are in agreement with the results of previous studies [14]. Some misconceptions also appear from the results of the students' answers which was presented in Figure 1. The model representation for a solution (which is a mixture) with a pure substance is different. Figure 1a has shown that students have been able to write the molecular formula of HCl (aq) but they have not been able to describe the interaction between water and HCl, even most (80%) students answered that the submicroscopic picture for pure HCl and HCl solutions is the same[22]. This answer showed that students have a
weakness in representing the submicroscopic level. Students also have not been able to connect the macroscopic, submicroscopic, and symbolic language levels. Student's answers also showed that students did not understand the concept of solution and pure substances. In representing the HCl solution consisting of water and pure HCl, we must consider the presence of water molecules.

![Image of submicroscopic representation](image1)

**Figure 1. Needs Analysis Data Collection**

The results of the interviews showed that preservice teacher in the first semester found difficulties to obtain a complete representation on the submicroscopic level due to the lack of independent teaching materials that could help them obtain a three-dimensional submicroscopic molecular picture. The main problem of difficulties in learning chemistry is the disconnection of the macroscopic, submicroscopic, and symbolic language/chemistry triplet representation [23]–[27]. This is due to the characteristics of chemistry studying an abstract phenomenon that cannot be observed, such as molecular structures, interactions between atoms, electron clouds, etc. [28] so that students as a preservice teacher need visualization assistance. Other information that was unearthed by researchers during pre-research was about student learning styles. The survey results showed that the student learning style was dominated by the audio-visual type, as presented in Figure 1b.

![Image of audio-visual learning](image2)

**Figure 2. Display of Chemistry Triplet Representation and Visualization in e-module**

To improve the quality of learning, a lecturer needed to know the characteristics of the learning style of the students because learning style was an important modality [29]. For example, learning characteristics that are suitable for students with visual types would be different from those of students who have auditory learning styles. The visual type matches the characteristics of the media that lead them to draw a lot, teaching materials that have a variety of colours and allow students to re-record the information they have received. Based on the findings in stage 1 (research and information collecting), researchers began to design the e-module. The e-module was also equipped with an animated video to strengthen students' understanding of the three levels of representation [30].
The characteristics of the e-module developed adapted to meet the needs at an early stage. e-Modules was prepared to intend students to connect the three levels of representation (chemistry triplet representation). An example of a chemistry triplet representation was presented in Figure 2. Many studies have found that one of the keys to obtaining a complete understanding of learning chemistry is the relationship between the macroscopic, submicroscopic, and symbolic levels [5, 31].

The concept of chemical materials presented in the e-module was directed to instilled a caring character for the environment. One of the themes used is the theme of acid rain that was associated with the acid-base concept. The use of environmental issues is proven to build students' thinking skills [32]. Figure 3 shows an example display of the use of environmental issues used in the e-module. Environmental issues was also used to bridge chemical content with students' real life. Character development was also carried out by integrating the unity of religious knowledge with the sciences. Figure 4a is an implementation of the integration of religious knowledge with science in material content, while Figure 4b was an implementation of the integration of religious knowledge with science in evaluation questions. The e-module was also equipped with a learning log. A learning log is a reflection sheet that has functions for students to write down whatever they have understood or what they have not understood. The learning log was filled in by students at the end of the lesson. Stephen stated that the learning log is an effective reflection tool in increasing student motivation, especially the visual learner type [33].

The e-module feasibility test was carried out by three experts consisting of two Chemists and one multimedia expert. Table 1 showed that the e-module meets the criteria very well according to chemists with an average score of 3.79, while the results of the validation by multimedia experts
showed in Figure 5 with a maximum score of 5. The next step was to test students with one to one evaluation to get qualitative input. The results of expert reviews and one to one evaluation activities were analysed to improve the quality of the e-module. The next step is to conduct limited trials on 15 students. These trials were done by giving questionnaires which were investigated with interview activities. Apart from getting an assessment, expert reviews also provide valuable input for improving the quality of e-modules.

Table 1. Results of Chemist Validation on e-Module

| Aspects                               | Mean Score From Expert Reviews | Criteria   |
|---------------------------------------|--------------------------------|------------|
| Feasibility of Contents               | 3.90                           | Very Good  |
| Presentation Aspects                  | 3.75                           | Very Good  |
| Chemistry Triplet Representation Aspects | 4.00                          | Very Good  |
| Unity of Sciences Aspects             | 3.50                           | Very Good  |
| Results Overall Aspects               | 3.79                           | Very Good  |

*maximum score of 4

The next step conducted a field test to determine the effectiveness of an e-module on critical thinking skills. In descriptive statistics, it can be seen that there was a difference in the average results of critical thinking skills between the control class and the experimental class, but to prove whether the difference was significant or not, it is necessary to carry out an independent sample t-test. The prerequisite test data consists of a homogeneity test and a normality test. The homogeneity test was carried out by using the Lavene test, while the normality test of the pre-test, post-test, and N-gain data carried out using the Saphirowilk test. The test results have shown that the N-Gain Score data was normally distributed and homogeneous, therefore the interpretation of the independent sample t-test output table was done by looking at the equal variances assumed part.
Table 2. The Result of Independent Sample T-test

| Data     | Sig Value | Criteria               |
|----------|-----------|------------------------|
| Pre-Test | 0.18      | not significantly different |
| Post-Test| 0.00003   | significantly different  |
| N-Gain   | 0.00002   | significantly different  |

The criteria used: accept Ho if the significance value $> 0.05$ and reject Ho if the significance value $< 0.05$. Data from the independent sample t-test on the N-Gain data using SPSSTM showed that the significance obtained was 0.00002 less than 0.05 so that Ho is rejected, so it could be concluded that the critical thinking skills of the control and experimental classes are proven to be significantly different. The experimental class has an average score of 87.15 while the control class has a lower average score of 70.85.

Figure 6. Student’s Responses

Students were also asked to assess the quality of the e-module whether it met the criteria of being interesting, helpful, and understandable, which are the criteria as a good science module [34]. The results of the e-module feasibility assessment according to students was presented in Figure 6. From the data presented, it could be concluded that the e-module developed has proven to be effective in developing students’ critical thinking skills. The developed e-module seeks to guide students to learn independently, thereby stimulating students to switch from lecturer-centre learning to active learning and can be done independently with the freedom of time and space that students have. As stated by [35] stated that a good learning media is said to have high quality if it motivates a transition from educator-centered learning to active and lifelong learning. The next step was to carry out e-module dissemination activities, one of which was through seminars attended by science lecturers.

4. Conclusion

Based on the research it can be concluded that (a) the e-Module fulfills the criteria Very Good in terms of material content with an average score of a chemist of 3.79, while in terms of the developed e-module media meets the Very Good criteria in terms of multimedia according to multimedia experts; (b) e-Module was proven effective in developing students' critical thinking skills significantly (c) Student response to e-Module gets a mean score of 3.64 which was in the very good category according to the student.
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