JPPIPA 8(4) (2022)

Jurnal Penelitian Pendidikan IPA

Journal of Research in Science Education

http://jppipa.unram.ac.id/index.php/jppipa/index

Development of A Learning Module Supported by Augmented Reality on Chemical Bonding Material to Improve Interest and Motivation of Students Learning for Senior High School

Achmad Saiful Whatoni[1*], Hari Sutrisno[2]

[1,2] Chemistry Education Study Program, Post-graduate, Faculty of Mathematics and Science, Yogyakarta State University, Indonesia

Received: August 23, 2022
Revised: October 12, 2022
Accepted: October 25, 2022
Published: October 31, 2022

Corresponding Author:
Achmad Saiful Whatoni
tonyachmad991@gmail.com

DOI: 10.29303/jppipa.v8i4.2057

Abstract: The chemical bonding material is a concept that requires visualization. For students to comprehend chemical bonding concepts better, molecular forms must be depicted in the materials. Consequently, a learning module that can show 3D things made from molecular structures is necessary. This study aims to create and evaluate an augmented reality-based learning module on chemical bonds while examining the similarities and differences between students' interests and learning motivation before and after utilizing the augmented reality-based learning modules. The product is designed utilizing a 4-D model, and this study uses a research and development model. A quasi-experimental method and one group pretest and posttest design were used to evaluate the module involving 53 students chosen randomly. A sample of Hotelling's T^2 test was used to analyze the student responses to the questionnaire about interest and motivation for learning. Descriptive quantitative analysis was used to analyze the data from the product quality assessment. The results showed that the developed augmented reality-supported chemical bonding learning module was very suited for chemistry learning and that there were variations between pre- and post-usage in student interest and motivation to study simultaneously or separately.

Keywords: Learning module; Augmented reality; Chemical bonding; Interest; Motivation

Introduction

Interest in learning can be interpreted as pleasure in learning, while student learning motivation encourages students to be more active in learning. Students' interest and motivation for learning play an essential role in learning and impact how well a lesson is developed and learned. However, abstract chemical concepts are thought to be challenging for students to comprehend. Students' motivation and interest in studying chemistry may decline (Fajri, 2021; Hamzah, 2011; Slameto, 2010; Üce & Ceyhan, 2019).

In keeping with the findings of Salta's research (2012), which found that various factors, including teaching methods, learning resources, and learning media, contribute to students' lack of interest and motivation in learning. In contrast to other subjects, chemistry lectures study matter's structure, properties, transformations, and energy. Because chemistry covers various challenging and abstract topics, students should study it more (Irwansyah et al., 2017; Liniarti, 2013; Sem et al., 2019; Suyati et al., 2018).

However, according to Üce and Ceyhan (2019), abstract ideas are challenging for students to comprehend. The instructional materials utilized are why students struggle to comprehend the chemical topic. Therefore, teachers must be competent in selecting the appropriate instructional strategies and resources to create a positive learning environment (Gazali & Yusmaita, 2018).

The ability to transform chemical phenomena into macroscopic, submicroscopic, and symbolic representations is necessary for students to understand chemistry cognitively. Submicroscopic visualization is crucial for students to comprehend chemical topics (Kelly & Hansen, 2017; Rakhmawan et al., 2018).

How to Cite:
Whatoni, A.S., & Sutrisno, H. (2022). Development of A Learning Module Supported by Augmented Reality on Chemical Bonding Material to Improve Interest and Motivation of Students Learning for Senior High School. *Jurnal Penelitian Pendidikan IPA*, *8*(4), 1916-1924. https://doi.org/10.29303/jppipa.v8i4.2057

Students need to be competent at visualizing concepts when learning chemistry. Suppose students cannot visualize various possible molecular events in their imaginations. In that case, they will not be able to comprehend submicroscopic images and apply them to macroscopic phenomena (Rakhmawan, 2018). However, because of their limited capacity for imagination, students find it challenging to picture how constituent parts of matter, like atoms, interact to form larger systems (Cai et al., 2014). For students to comprehend the level of submicroscopic images in chemistry, it is quite difficult for them to visualize (Tasker & Dalton, 2006).

One of the chemistry topics required for visualization is the molecule's shape in the electron domain theory. In order to help students better understand the concepts of chemical bonding, molecules in chemical bonds must be described in terms of their shapes. Students must accurately understand fundamental chemical bonds and chemical principles. One of the reasons why students struggle with this topic's principles is the use of traditional education. This may cause students to become less interested in topics that hinder their academic success. This is why it is necessary to provide students with a three-dimensional submicroscopic depiction to help them visualize the shape of a molecule. Doing so conveys the information more clearly (Nahum et al., 2010; Rajmah et al., 2017; Sahin & Yilmaz, 2020). According to Kozma and Russell (2005), molecular simulations, models, and animations have the potential to aid in the study of chemistry in general and a deeper comprehension of the idea of chemical bonds in particular. Students exhibit greater motivation and interest (Abdolatiff & Narod, 2009). The illustration might use technology, like other smartphone applications (Wahyudi, 2014). As a result, educators must provide instructional materials that allow students to visualize 2D molecular objects in 3D. A form of technology that is currently being developed is augmented reality (Kamelia, 2015).

According to various studies, using technology to offer educational materials can make learning more engaging, motivating, stimulating, and effective for students (Singhal et al., 2012). Augmented Reality (AR) concepts are one of the most current technologies with the potential of being incorporated into education and used by educators in science instruction (Ziden, 2022). AR is defined as technology in which the real world is augmented by computer-generated content like text, images, and videos. The users may interact with the virtual objects that are placed within the real scenes around them and experience the most natural and real human-computer interaction. AR provides a better understanding and experience for the students due to its features in portraying 3D images (Majeed, 2020; Tekederea, 2016). Since AR can be utilized on smartphones, it is now more accessible and does not require special equipment and students can observe experiments easily from several angles. This way, dangerous or hazardous experiments may be presented safely. One benefit of employing AR technology is that it may be utilized as a learning tool that offers 3D visualization that students can regularly use (Irwansyah, 2018; Khan, 2019; Molnár, 2018). Based on the result of the research in Turkey shows that the use of AR technologies in education is efficient, successful results are obtained, and the results are statistically significant (Tekederea, 2016).

The chemical bonding learning module can also use AR-based interactive learning materials. Developing an interactive module with 2D graphics that can be projected with a program that can visualize the many kinds of chemical bonds in 3D would make it simpler for students to recognize different kinds of chemical bonds and molecular structures. The image visualization in AR-based apps includes a description of the kinds of compounds, geometries, and chemical bond structures that can be scanned using a smartphone that turns 2D photographs into 3D. Students' motivation to learn about chemical bonds should increase with the development of AR-based smartphone technologies.

The use of Augmented reality as a learning tool is very suitable for students to study chemistry bonding material as it is show how the real picture of a molecule looks. Implementing AR-based learning tools can be very beneficial in improving student interest and motivation for learning chemistry. It is very important for the teacher to create interesting learning tools for the students (Ziden, 2022). However, as many benefits offered by augmented reality, its seldom implemented in the classroom (Mustaqim, 2016). As the reason above, this research is important to conduct to know how significant its benefit is for students in learning chemistry, especially in chemistry bonding material. Specifically, this research aims to develop, analyze the module’s feasibility, and to know whether learning module-based augmented reality can improve students’ interest and motivation.

Method

This study's research type is research and development (R&D). A 4-D model was used to create a learning module for chemical bonds that supports augmented reality. The 4-D model of Thiagarajan, Semmel, and Semmel is the development model used in this study (1974).

The four steps of the development process in this study are defined, designed, develop, and disseminate. In order to construct learning modules, the define stage tries to identify and specify the developmental instructional requirements. Preliminary analysis, student analysis, task analysis, concept analysis, and objective problem formulation are all carried out during this first step.

The design of the learning module is then completed based on the results from the defined stage. A prototype is an item created at this point. After being modified and accepted by qualified lecturers, the prototype can move on to the following step.

The first iteration of the product design (prototype) is then developed into a learning module with augmented reality support that is prepared for validation and testing. Lecturers with expertise in both the topic and the media will validate the learning module. With augmented reality, constructed as suggestions and responses, assessors will provide feedback to the learning module. Following updates based on comments or corrections from knowledgeable lecturers, the learning module will undertake initial testing, including a feasibility test to peer reviews, chemistry teachers, and readability tests by students using evaluation sheets.

Students can test a module when it has been deemed excellent and appropriate for use. Module packaging is accomplished by printing the module and uploading an augmented reality application. The module and AR media were then distributed to chemistry teachers at the schools where the trials were held for dissemination.

Learning modules with augmented reality support were then tested on 53 SMAN 1 Praya Timur students by appointing a school at SMA Negeri 1 Praya Timur and randomly selecting two class X science students using a simple random sampling technique to determine the module's effectiveness in increasing students' interest and motivation in learning. The field trial used a quasi-experimental design with a one-group pretest-posttest.

The data was collected through observation, interviews, assessments, and questionnaires. Several instruments were used in this study to collect data, including interview guidelines, observation guidelines, assessment sheets by expert lecturers, peer reviews and chemistry teachers, readability test sheets, and questionnaires of interest and student motivation. The assessment sheet and questionnaire use the Linkert scale, which has five scales: Strongly Agree (SS) = 5, Agree (S) = 4, Doubtful (RG) = 3, Disagree (TS) = 2, Strongly Disagree (STS) = 1.

The data analysis technique used in this study is qualitative and quantitative data analysis. The qualitative analysis explains the development process that leads to the product's feasibility. A quantitative analysis approach is used to determine the product's effectiveness and the percentage of the product's contribution to the interest and motivation of students' learning.

Expert judgment is used to determine theoretical validity in each field. Theoretical validity is assessed in stages based on the level. The first stage involves testing the learning module's theoretical validity using augmented reality, a learning interest questionnaire, and a learning motivation questionnaire. The next stage is the theoretical validity of the chemical content used, namely chemical bonds. Empirical validity was determined by testing learning modules with augmented reality support, learning interest questionnaires, and learning motivation questionnaires outside the research sample that had previously received chemical bonding material. Then, the data were analyzed with the Rasch Model using winstep software. The Cronbach's Alpha model was used to analyze questionnaire reliability tests as well as interest and motivation in this study (Hair et al., 2010).

The feasibility of learning modules with augmented reality support was evaluated using quantitative data on a scale of 1 to 5, with one being very poor and five being very good. The average score can be calculated using the following formula based on the quantitative data obtained (Arikunto, 2009).

$$\bar{X} = \frac{\Sigma X}{n} \tag{1}$$

Description:
$\bar{X}$ = Score Average
ΣX = Total Score
n = Respondent

The percentage yield formula can then be calculated as follows:

$$Score\ (\%) = \frac{Score\ Obtained}{Maximum\ Score} x\ 100\% \tag{2}$$

Product Feasibility Categories Based on the score (%) shown in Table 1.

Table 1. Shows Product Feasibility Categories Based on Criteria.

Score (%)	Category
81-100	Very feasible
61-80	feasible
41-60	Adequate
21- 40	Less feasible
< 21	Not feasible

Multivariate tests and advanced tests were applied in this study. The data for this study are analyzed using multivariate analysis and two dependent variables: interest and motivation to learn. Data analysis techniques such as multivariate analysis were used in this study. To assess differences before and after treatment, one sample Hotelling T^2 Test was used. If H_0 fails Hotelling's T^2 test, a post-hoc test is performed. Follow-up tests were performed on each dependent variable to determine the difference between before and after learning with augmented reality support, particularly students' interest and motivation. This is necessary because differences in the independent variables do not always result in differences in the dependent variables. The procedure of this research method is shown in Figure 1.

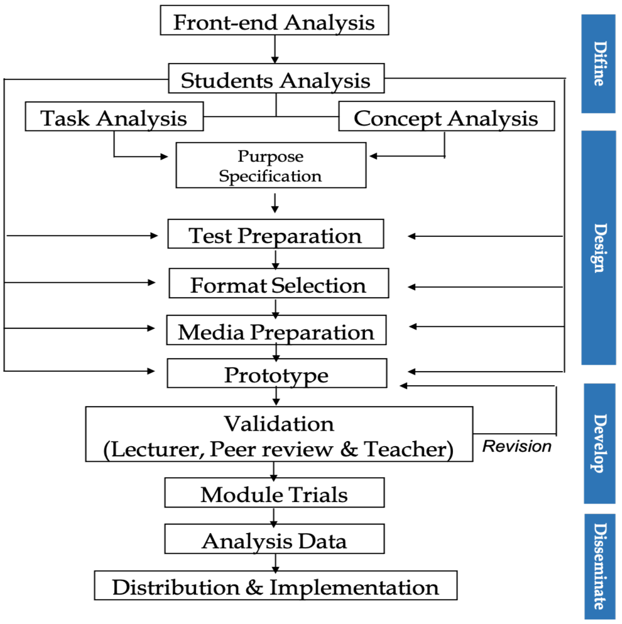

Figure 1. Research Flowchart

Result and Discussion

Learning Module Characteristics supported by Augmented Reality

The development of learning modules with augmented reality support is based on the limitations of teaching materials based on cutting-edge technology like augmented reality. In Indonesia, the use of AR-based learning media is still uncommon. Augmented reality, or AR for short, allows students to visualize abstract or difficult-to-imagine concepts and then relate them to the real world (Boyles, 2017; Syawaludin et al., 2019).

The developed learning module is printed in A5 size in full color, making it very portable and appealing. According to Heryani and Rustina (2018), printed teaching materials have advantages such as being more comfortable to read and having good delivery quality, such as the ability to present numbers and data. Printed teaching materials are self-sufficient, meaning they can be used directly or require no other tools. Learning modules typically include the following components: 1) formulation of learning objectives, 2) student activities, 3) worksheets, 4) evaluation sheets, and 5) key evaluation sheets (Budiono & Susanto, 2006; Mularsih, 2017).

The augmented reality-based chemical bond learning module includes instructions for use, concept maps, essential competencies, learning indicators, learning activities, learning objectives, material descriptions, sample questions, competency tests, independent assignments, self-assessments, glossaries, and scoring guidelines. According to Rahdiyanta (2016), a learning module that can increase learning motivation must have the following characteristics: a) self-instructional, b) self-contained, c) stand-alone, d) adaptive, and e) user-friendly.

The developed learning module contains learning objectives in each learning activity, examples of how to work on the questions, and illustrations of material presented in the form of videos provided in barcodes that are used if students do not understand the material, as well as self-assessments and scoring guidelines to determine their level of mastery of the material, and there is a reference or reference material, thus enabling students to (self-instructional). The developed module also includes the necessary chemical bonding material, allowing students to thoroughly investigate chemical bonds because the entire chemical bond material has been packaged (self-contained). The developed chemical bond learning module is also highly adaptable to technological advancements. The module has been integrated with an augmented reality application capable of displaying molecular shapes in 3D in real-time (adaptive). Furthermore, the module's final feature, namely (user-friendly) in chemical bond module with augmented reality support, already provides instructions for using AR modules and applications. The module uses simple, easy-to-understand language, and a glossary is available as a dictionary for terms that are not common so that students or module users can be helped and facilitated.

Augmented reality applications are created with Unity and the Vuforia engine. Before creating the application design, first, create a target image in Photoshop, then create a 3D animation in the form of a molecule in the Avogadro program, and finally in a blended format in the program blender. This AR application runs on a smartphone with a minimum Android system specification of Jelly Bean, 512 MB RAM, 1 GB memory, and a camera resolution of 5 megapixels. With these specifications, students can easily install AR applications because the application is only 42 MB in size. This makes it very simple for students to use AR applications because they do not require a high-spec smartphone. The display of learning modules and augmented reality applications are shown in Figures 2 and 3.

Figure 2. Cover of chemical bonding module

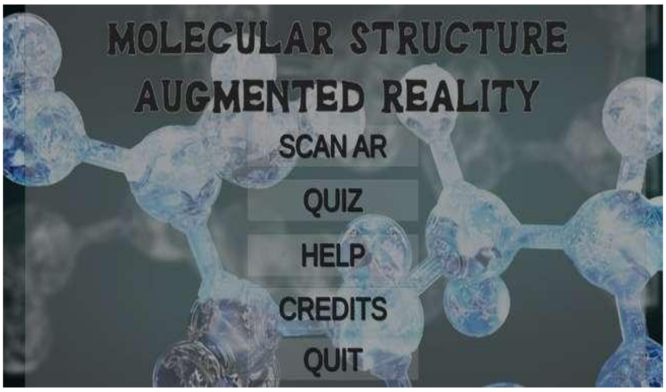

Figure 3. Main menu's display of augmented reality

Quality and Feasibility of Augmented Reality Supported Modules

Before being tested, the chemical bond learning module with augmented reality support is first corrected by the supervisor and then by expert lecturers to assess the quality and feasibility of the material and product media developed. The correction results indicate that the learning module with augmented reality support is suitable for use with revision. Furthermore, the revised module is tested in the initial field, including readability and feasibility tests. The results of the feasibility and readability tests are shown in Tables 2 and 3.

Table 2. Peer Review and Chemistry Teacher Feasibility Test Results

Aspect	Average	Feasibility (%)	Kategori
Learning	4.51	90	Very feasible
Material	4.58	91	Very feasible
Visual display	4.59	91	Very feasible
Software	4.52	90	Very feasible

Table 3. Student Readability Test Results

Aspect	Indicator	Average	Description
Material	Clarity of the presented material	4.65	Complete material descriptions are written in standard language that is easy to understand
	Language Usage	4.58	Using clear language and comprehensive material explanations in writing
	Material and Question Relevance	4.38	The questions are precise, simple to comprehend, and relevant to the subject
Visual Display	Matching font colors	4.38	All font colors contrast with each other and are easy to read.
	Background suitability	4.42	The background is appropriate, not distracting, and aesthetically pleasing.
	Font compatibility	4.46	The typeface is acceptable and easy to read.
	Animation selection	4.31	An engaging and simple animation
Software Engineering	Clarity of the application usage	4.35	The media instructions are stated clearly and simply.
	Media accessibility	4.31	The media is simple to use without the assistance of others' instructions
	Media Innovation and Creativity	4.58	fascinating and inventive educational media
	Programming language and operating system compatibility	4.54	The software is lightweight, does not crash, and has a minimal file size.
Total		4.45	Excellent

The Feasibility Test was evaluated by a panel of five chemistry education graduate students and practitioners, precisely five high school chemistry teachers. Peer review and chemistry teachers evaluated the feasibility of four aspects of the learning module supported by augmented reality: a) learning; b) material; c) visual display; and d) software engineering. According to the results of the product feasibility test conducted by peer reviews and chemistry teachers, as shown in Table 2, every aspect assessed in the developed learning module is in the very feasible category, with a feasibility percentage of approximately 90-91%. The developed product is at least feasible, allowing this development product to be tested on students (Khotim, 2015). Field trials or applied trials were conducted on 53 students from class X science.

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The module readability test was validated by 26 students from SMAN 1 Praya Timur's class XI science. Students assess the readability of three aspects of the learning module with augmented reality support: a) material, b) visual display, c) and d) software engineering. Table 3 summarizes the readability test results. The average value obtained is 4.45, indicating that the chemical bond learning module with augmented reality support is excellent. According to Ananingtyas (2020), the readability of the module for students or module users is critical because it can affect module users' understanding of the material.

Twenty-six SMAN 1 Praya Timur's class XI science students validated the module readability test. Students assess the readability of three aspects of the learning module with augmented reality support: a) material, b) visual display, c) and d) software engineering. Table 3 shows the readability test results. The average value obtained is 4.45, indicating an excellent chemical bond learning module with augmented reality support. According to Ananingtyas (2020), the readability of the module for students or module users is critical because it can affect module users' understanding of the material. The module's ability to comprehend language, presentation, content, and advantages impact how well it facilitates learning (Alias et al., 2013).

Application of Learning Modules Supported by Augmented Reality to Determine Differences in Students' Interests and Learning Motivations

The application of the chemical bond learning module with augmented reality aims to see if there are any differences in students' interest and learning motivation before and after using the learning module, either simultaneously or individually, and to determine whether there are differences in students' interest and motivation to learn concurrently before and after using the learning module on chemical bonding material with augmented reality support. The Hotelling T^2 test was used to process the pretest and posttest data on interest and motivation. The results of the Hotelling T^2 test are shown in Table 4.

Table 4. Hotelling T^2 Test Results

Test	F	Hypothesis df	Error df	Sig.	Partial Eta Squared
Hotelling's Trace	5.11	2	44	0.01	0.188

Based on the results of the Hotelling T^2 test in Table 4, a significance value of less than 0.05 was obtained in the Hotelling's trace group, which was 0.010. These findings indicate that H_0 is rejected, implying differences in students' interest and learning motivation before and after using the learning module on chemical bonding material with augmented reality support. Students' interest and motivation were higher after using the chemical bond learning module with augmented reality support than before. The practical contribution is then calculated using partial eta squared. The practical contribution of 18.8% is more significant after using the learning module with augmented reality support on the interest and motivation to learn simultaneously than before using the module. Using the chemical bond learning module with augmented reality supports identifying individual differences in interests and motivations. Based on the results of the various tests shown in Table 5.

Table 5. Test results of Between-Subject Effects

Dependent Variable	df	Mean Source	F	Sig.	Partial Eta Squared
Interest	1	114.140	9.333	0.004	0.172
Motivation	1	150.918	4.856	0.003	0.097

Based on the results of the various tests shown in Table 5, the significance value of the interest variable is known to be 0.004, which means the significance value is less than 0.05, and thus H0 is rejected. This demonstrates differences in students' interest in learning before and after using the chemical bonding material learning module with augmented reality support. Furthermore, the value of Sig. of 0.033 on the variable of learning motivation indicates that the significance value is less than 0.05, so H0 is rejected. This also demonstrates differences in students' learning motivation before and after using the chemical bonding material learning module with augmented reality support.

Based on the partial eta squared value in Table 5 multiplied by 100%, it is identified that the chemical bonding learning module with augmented reality support contributes 17.2% to students' learning interest and 9.7% to students' learning motivation. Based on statistical findings, it is possible to conclude that using learning modules with augmented reality support significantly impacts students' interests and motivation. This is consistent with Chen and Liu's (2018) study, which found that AR learning activities can increase students' interest and motivation in learning chemistry for both direct and long-term effectiveness. AR learning activities are also superior to teaching methods such as demonstrations or lectures. Similar to Zhang et al. (2014) research, experience in the human field and AR applications effectively impact student interest retention. AR applications can significantly impact chemistry education and potentially expand to other areas of education. AR plays a significant role in improving the absorption of new knowledge while solving problems in settings that were more realistic, AR is no longer perceived as a novel concept and is expanding in tandem with the expansion of e-learning platforms. This cutting-edge educational tool has also assisted students in visualizing complex 3D concepts and understanding molecular structure at the molecular level. Furthermore, AR applications have increased students' interest and motivation to learn chemistry, and they prefer to use this technology over other teaching materials they have encountered during their chemistry studies (Abdinejad et al., 2021; Abdullah, 2022).

Conclusion

Based on the study's results, it is possible to conclude that the developed chemical bond learning module with augmented reality support is very suitable for use in chemistry learning, particularly in chemical bonding material. Before and after using the chemical bond learning module with augmented reality, there are differences in students' interest and motivation to learn simultaneously or individually. The chemical bond learning module with augmented reality support effectively contributes 18.8% to students' interest and motivation to learn simultaneously, 17.2% to student interest in learning, and 9.7% to learning motivation.

Acknowledgments

The author expressed gratitude and appreciation to Prof. Dr. Hari Sutrisno, M.Si as supervisor, who assisted in the writing of this thesis, as well as the staff at SMAN 1 Praya Timur, who provided me with the opportunity to conduct research at the school.

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