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Development of Augmented Reality-Based Modules for Chemistry Bonding Materials at Taman Mulia Pontianak High School

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Abstract: Onventional teaching media used by teachers in teaching chemical bonding has not been able to facilitate students in understanding the concept of chemical bonding because the media used are still in two-dimensional form. Therefore, it is necessary to develop three-dimensional teaching media capable of visualizing the concept of chemical bonding, one of which is augmented reality (AR). This study aims to determine the validity and practicality of an AR-based chemical bonding module. The research type used is Borg and Gall's development research model, modified into 7 research stages. The research sample consisted of 30 students selected using purposive sampling technique. The results of material, media, and language validation analysis indicate that the developed AR-based module is valid with validity percentages of 96.66%, 81.47%, and 88.33%, respectively. Practicality analysis using a practicality questionnaire shows that the developed AR-based module is practical with a practicality score of 93.88%. Therefore, the AR-based module is highly suitable as an alternative teaching media for the topic of chemical bonding

Keywords: Augmented reality; Chemical bond; Development; Learning resources; Module

Introduction

Education is a crucial component in determining the quality of human resources in both developed and developing countries. In this advanced era of globalization, education has become an essential necessity for every individual to keep up with technological advancements and the times (Silaban, 2021). The development of educational technology, including learning media infrastructure and advances in various disciplines, as well as mastery of information technology and learning innovation techniques, must be implemented in education (Qibtiyah & Sukarmin, 2022). Educational practitioners and institutions must be independent in discovering knowledge innovations and media to adapt to technological advancements (Suhirman, 2016). Kristiawan (2014) in his research reported that teachers have not been able to adapt to technological advancements, and they are unaware of the curriculum change to Curriculum 2013.

Research findings Rohman & Susilo (2019); Winda & Dafit (2021), it shows that teachers have difficulty operating computers. The gap between advanced digital skills of students and the traditional tendencies of teachers results in varying understandings, threatening the role of teachers in the rapidly developing era of globalization (Angraini et al., 2017). Current technology allows students to have quick and unlimited access to information, challenging teachers to remain the primary source of learning. Teachers need to adapt to these changes to guide, direct, motivate, and design classroom learning effectively (Effendi & Wahidy, 2019; Salsabila et al., 2021). Good chemistry education provides scientific understanding and relevance of chemical concepts in daily life, encouraging learners to construct their own understanding from the material studied (Djarwo, 2018; Izzatunnisa et al., 2019).

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However, the facts in the field show that students have difficulty understanding chemical concepts. This difficulty is caused by the lack of integration of technology with the teaching methods used by teachers in the classroom for abstract chemical concepts. The integration of technology in learning can be one of the opportunities to develop appropriate media that align with students' learning needs (Tri Astuti & Marzuki, 2018). One of the subjects that students find difficult to understand is chemical bonding. The topic of chemical bonding involves both abstract and concrete concepts. Difficulty in understanding one concept can hinder comprehension of related concepts, as a comprehensive understanding of fundamental concepts is necessary to grasp more complex chemical concepts (Rosawati, 2016; Syaribuddin et al., 2016).

Research findings Apriani et al. (2021); Mashami & Khaeruman (2020), it shows that students have difficulty learning chemical bonding because it generally involves abstract concepts. As a result, in chemistry education, learners find it more challenging to construct meaning from chemical concepts compared to concepts in other natural sciences. One of the media hat teachers use to explain chemical bonding is modules. Modules are books written for students to learn independently without teacher guidance, containing basic components of instructional material: introduction, core, and conclusion, tailored to students' interests, attention, abilities, characteristics, and needs (Nurdyansyah, 2018; Sirate & Ramadhana, 2017). The use of modules in teaching and learning activities does not only focus on the teacher's activities but also actively involves students in learning. Using modules also fosters independent learning processes (Zaidah & Wijaya, 2021). However, the use of printed modules to explain the process of chemical bond formation and molecular shapes has its limitations because it only depicts them in 2-dimensional form. Therefore, in this research, printed modules will be developed with the assistance of augmented reality to make them more interactive (Fahrurrozi et al., 2019).

Augmented reality (AR) integrates 3D virtual objects into the real environment. Developing chemistry learning modules with AR (Ariska et al., 1970; Iqbal et al., 2022), especially for chemical bonding topics, is crucial because it aligns well with the intended media. Research on developing modules for chemical bonding has been extensively reported (Irfandi et al., 2018; Rahma et al., 2017). However, based on literature review, no research has been found on the development of AR-based modules for chemical bonding topics (Sousa & Romão, 2021). Therefore, this study aims to develop AR-based modules on chemical bonding with the hope of facilitating students in learning the process of chemical bond formation (Agussalim et al., 2021; Macariu et al., 2020).

Method

This type of research is research and development (R&D). The method used is R&D (Research & Development), and the development model employed in this study is Borg and Gall's development model modified into 7 steps: research and information collecting, planning, developing preliminary form of product, preliminary field testing, main product revision, operational field testing revision, and final product revision (Kemayasha, 2012; Saliatunisa et al., 2021).

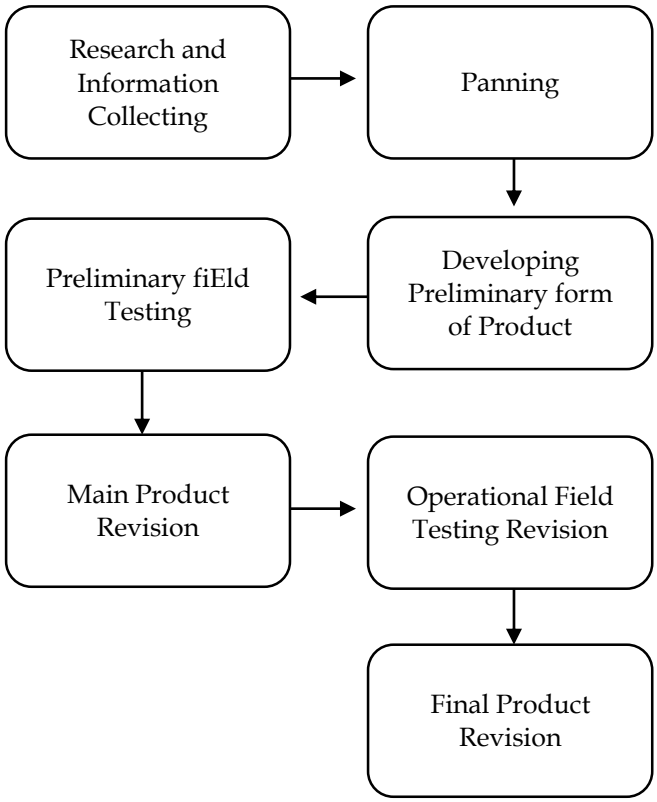


Figure 1. Borg and Gall Development Model Design

This research was conducted at Taman Mulia Pontianak High School with a population of 30 students from Grade 10 Science. The data collection techniques used were as follows: Interviews conducted through question and answer sessions with chemistry teachers and students at Taman Mulia Pontianak High School. Questionnaires included a validation questionnaire for subject matter experts, media experts, and language experts, as well as a questionnaire to gauge teacher and student responses aimed at assessing the validity and practicality of the developed product, which is an augmented reality-based module. Meaningful documentation included records of past events.

Documentation methods included photos, videos, and documentation throughout the research activities. Based on the validation results from experts assessing the content, language, and media, calculations were performed using Formula (1) (Ma'aniyah & Mintohari, 2019).

$$Percentage = \frac{\Sigma score\ obtained}{highest\ score} \text{ x } 100 \quad (1)$$

Result and Discussion

The result of this research is an AR-based module in high schools. This study modifies the Borg and Gall 7-step development model with the result (Rohmaini et al., 2020):

Research and Information Collecting

In this stage, the research conducts needs analysis, literature review, and identifies factors causing problems that necessitate the development of a new product. Needs analysis involves the process of data and information collection used as supporting tools in creating Augmented Reality-based module (Apriani et al., 2021). The results of the needs analysis indicate that the media to be developed can assist learners in their learning process. Literature review examines relevant theories and previous research findings related to Augmented Reality-based modules to optimize student learning outcomes (Mashami et al., 2021). The literature review results indicate that the development of AR-based media is effective for use by learners. The AR developed uses the Borg and Gall model, consisting of 7 stages (Rusianti et al., 2019). Problem identification is conducted by analyzing factors that cause issues, thus necessitating the development of a new product. In this stage, researchers conduct observations and interviews to gather information about the chemistry learning process at Taman Mulia Pontianak High School. The results of observations and interviews show that the problem experienced by students during the learning process in class relates to chemical bonding topics. During the chemical bonding learning process, teachers only use textbooks and PowerPoint presentations. Consequently, student motivation and focus decrease, and the learning effectiveness is reduced (Pardede et al., 2022).

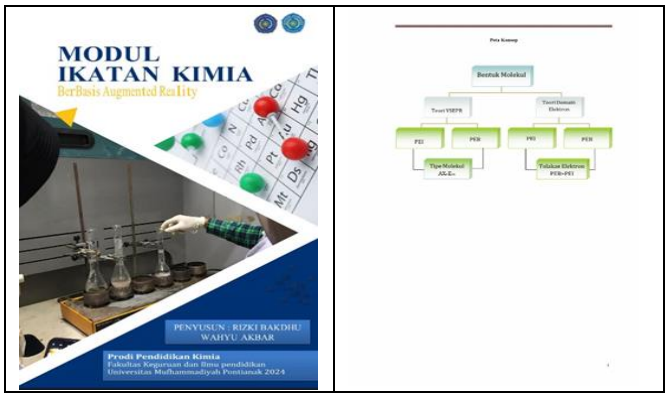
Planning

The planning stage is the initial step in product development. The planning stage begins with formulating the objectives to be achieved by the developed media. Based on the analysis results, the next stage is the design or product planning stage, which includes: Planning the design of the learning media. In this stage, researchers design the product according to the characteristics of the learners and the materials to be used in the augmented reality-based module learning media. Developing an innovative learning media to motivate students in learning and assist teachers in delivering materials more effectively during the learning process. The media to be developed by the researcher is an augmented reality-based module. This learning media incorporates augmented reality features. Augmented reality is a technology that integrates two-dimensional or three-dimensional virtual objects into a real three-dimensional environment and projects these virtual objects in real-time (Wang & Chen, 2020). In creating this AR media, tools such as Vuforia, Unity 3D, SketchUp, and Android are utilized. The principle of AR generally involves markers, where the camera is calibrated to detect the provided markers. After marking the marker pattern, the webcam calculates whether the marker matches the database. If it does not match, the marker is not processed; however, if it matches, the information from the marker is used to display previously created 3D objects (Lah et al., 2024). The preparation of this instrument aims to facilitate the researcher in data collection. Research instruments needed for this study include expert validation sheets to assess validity and student response questionnaires to assess practicality. Material validation involved three validators: Ms. Thea Amira Vashti, S.Pd, a chemistry teacher at Taman Mulia Pontianak High School; Mr. Sui Kiun, S. Hut., MM, a teacher at SMA N9 Pontianak; and Ms. Selvia L, S.Pd, a teacher at SMA N1 Silat Hilir. Validation testing was conducted with 10 assessment questions, each scoring a maximum of 4. The final result obtained was 95%, indicating that the materials used are valid and suitable for use.

After validating the content with subject matter experts, the next step involved validating the language, which was conducted with three language validators: Mr. Sui Kiun, S. Hut., MM, a teacher at SMA N9 Pontianak; Ms. Dewi Leni Mastuti, M.Pd, a lecturer at IKIP PGRI Pontianak; and Ms. Sinta Monica, S.Pd, a teacher at Taman Mulia High School. The validation process included 10 assessment questions, each with a maximum score of 4. The final result obtained was 88.33%, indicating that the language used in the media met the criteria of being highly valid and very suitable for use, although there were still some corrections needed for incorrect writings. Subsequently, media experts were validated with three validators: Mr. Fathurrahman, S.Pd, a teacher at Taman Mulia Pontianak High School; Mr. Asrul Abdullah, a lecturer at UM Pontianak. The validation process consisted of 9 questions, each scoring a maximum of 4. The final result obtained was 83.47%, indicating that the media is valid and highly suitable for use.

Develop Preliminary of Product

The product assembly is based on the designed product and then the product is manufactured. All components prepared in the design stage are assembled into a unified interactive learning media product based on Augmented Reality modules, created to be as appealing as possible to ensure students are engaged and interested in the learning process. The results of the product assembly are shown in Figure 2.



(a) (b)

Figure 2. Product Development Design

The development of this product continues into the expert validation process. In this stage, validation is carried out by experts for the instructional media, learning material design, the learning process, and the research instrument (response questionnaire). Validation is conducted to determine the validity of the developed product. Below is Table 1 outlining the validity criteria:

Table 1. Table of Validity Criteria

Evaluation	Score (%)	Criteria
Language expert	88.33	Very valid
Matter expert	96.66	Very valid
Media expert	81.47	Very valid

(a) (b)

Figure 3. Module cover display (a) before revision and (b) after revision

Revision based on the validity analysis from validators and the first stage product testing. By analyzing the shortcomings identified during validation and product testing, these issues can be promptly addressed. Validation was conducted with 9 validators comprising 3 language experts, 3 media experts, and 3 subject matter experts. Several suggestions or improvements were proposed. Regarding the module cover, validators recommended correcting writing errors in the augmented reality section and the Muhammadiyah section.

Preliminary field testing

In this study, preliminary field testing was conducted at SMA Taman Mulia Pontianak, involving a small-scale test with feedback questionnaires provided to teachers and students. This small-scale test was conducted with a chemistry teacher and 10 students, each receiving a feedback questionnaire during the field test. The results of the preliminary field testing showed that the average practicality score from the small-scale test involving 10 students was 90.41%, categorized as highly practical. The small-scale test aimed to provide insights for the large-scale trial. Due to the highly practical results obtained from the small-scale test, the product can proceed to the large-scale trial without revisions. Below is Figure 3 displaying the results of the small-scale test:

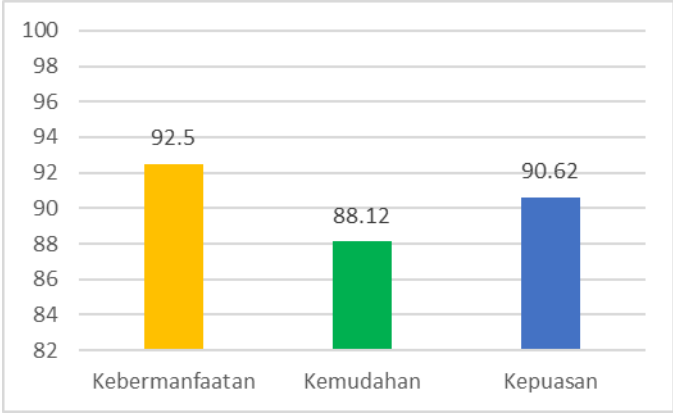


Figure 4. Data from the small-scale trial

Preliminary Product Revision

Based on the results of the initial field trial, there were no comments or suggestions provided by the respondents. Therefore, a second trial was conducted.

Main Field Testing

The main field trial involved several samples, engaging 30 students from the tenth-grade science class and one chemistry teacher at SMA Taman Mulia. Feedback questionnaires were distributed to assess participants' evaluations of the developed product. The

results of the main field trial indicated that the media used was highly practical during learning sessions, with an overall average score of 93.88%. Below is Table 1 presenting the data from the large-scale trial.

Table 2. Results of the large-scale trial

Aspect	Intervals	Category
Usefulness	94.58	Very practical
Convenience	93.95	Very practical
Satisfaction	93.12	Very practical

Table 2 shows that the average practicality score in the large-scale trial was 93.88%, categorized as highly practical. The high percentage of practicality is attributed to AR, which facilitates students in visualizing molecular shapes concretely (Mazzuco et al., 2022). The advantage of augmented reality lies in its visually appealing display, capable of presenting three-dimensional objects with animations that appear as if in a real environment. Therefore, augmented reality is expected to be used as an alternative learning media to introduce concepts related to molecular shapes, thus engaging users effectively (Wardani et al., 2023). Augmented reality can help students understand chemical concepts more deeply and motivate active engagement in the learning process (Damanik et al., 2024). Augmented reality has been applied in the context of chemistry education at various levels, from elementary school to university (Rita & Guspatni, 2024).

Operasional Product Revision

Product revisions are always conducted after the product is implemented or tested. This is done especially when new challenges arise that were not considered during the design phase. Feedback and suggestions from the main field trial can be used as considerations in revising the Augmented Reality-based Module product. The product results are shown in Figure 5.

(a) (b)

Figure 5. Final product (a) module cover page (b) Scan AR barcod

Conclusion

The Augmented Reality (AR)-based Module on Chemical Bonding developed is suitable for use as a learning media, with average validity and practicality scores in small-scale and large-scale trials of 92.41% and 88.82%, respectively. The advantages of AR-based modules as learning media lie in their engaging visual displays, capable of presenting three-dimensional objects and animations as if in real environments. Therefore, augmented reality is expected to serve as an alternative learning media to introduce concepts related to molecular structures, facilitating easier understanding of chemical bonding for students.

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Author Contributions

The study idea and plan were developed by RB. Investigation was conducted by RB, RF, and DH. Data were analyzed and interpreted by RB, RF, and DH. RB and RF wrote the manuscript and conducted major revisions to ensure its quality.

Conflicts of Interest

The authors declare no conflict of interest

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