THE DEVELOPMENT OF 3D INTERACTIVE MULTIMEDIA ORIENTED SPATIAL VISUALLY ON POLAR AND NONPOLAR COVALENT BONDING MATERIALS

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ABSTRACT

Visual-spatial is needed to improve submicroscopic understanding, such as polar and nonpolar covalent bonding materials. Not many 3D interactive multimedia have been developed with visual-spatial orientation. This research aims to produce 3D interactive multimedia with spatial-visual orientation on polar and nonpolar covalent bond materials suitable for use. The research design uses an R&D (Research and Development) research model developed but restricted to a limited trial step. The eligibility criteria include validity (content and construct) and practicality. The validity criteria are based on the results of the validity assessment data from three validators. Practicality criteria are based on the assessment given by three chemistry teachers shortly after the visual-spatial-oriented 3D interactive multimedia trial. Overall data were analyzed descriptive-quantitatively. The results of the study concluded that the developed 3D interactive multimedia meets the eligibility requirements. Each validation indicator in 3D interactive multimedia receives an assessment from the validator with mode (Mo) at least 4 in the score range 1-5 and the percentage of agreement (R) between validators above 75%. The 3D interactive multimedia meets practicality requirements because each indicator receives an assessment from the user students with (Mo) at least 4 in the score range 1-5. The percentage of agreement (R) between user students is above 75%.

Keywords: covalent bonds, interactive multimedia, visual-spatial

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1. INTRODUCTION

The chemistry bonds, as are chemistry in general, in its learning process include three levels of thinking, there are observable macroscopic, symbolic and unobservable submicroscopic (Taber et al., 2012; Vrabec & Prokša, 2016). Macroscopic levels such as observing the process of chemical reactions that produce new material seen from changes in temperature, discoloration, odor formation or other materials lost during chemical reactions. Submicroscopy levels for instance the movement of electrons, atoms, molecules, and chemical bonds. Symbolic levels for example chemical formula writing, empirical formulas, and chemical equations (Treagust et al., 2003). These three levels must be presented by teachers or lecturers so that there is no misinterpretation. Concepts in chemical bonds are in sub-microscopic part or molecular part of an abstract nature (Nahum et al., 2010; Tasker, 2014; Zhou et al., 2014).

The primary object of study of chemical bonding material is polar and non-polar covalent bonds which are abstract objects (Bergqvist et al., 2013; Nahum et al., 2010). Therefore, students’ must be able to build mental visualization of the form of three dimensional covalent bonds appropriately to be able to properly study chemical bonding materials (Tuvi-Arad & Gorsky, 2007).
process of building a mental visualization of covalent bond form requires the ability to understand structure formulas and translate them into three-dimensional representations (Jiang et al., 2016). This is because the chemical bonds and symmetry elements are generally represented in two dimensions in textbooks. These cognitive processes can be performed well by students if they have a high spatial visualization (Bende et al., 2015; Yaghoob & Hossein, 2016). Spatial visualization is the ability to accurately understand the shape and orientation of three-dimensional objects based on their twodimensional representation (Anggriawan et al., 2017; Barnea, 2000).

Based on those problems, the causative factors of difficulty include because of someone’s mind needs to imagine between the 3D structure of a molecule and the image printed in 2D (Abraham et al., 2010; Tasker, 2014). In addition, the lack of ability to integrate between definitions and rules, mastery of observation techniques, and low awareness of spatial visual structures. This is understandable, because when studying all three aspect of chemical bonds, someone’s mind is required to actively imagine the spatial order of atoms or clusters in a molecule (Mohamed-Salah & Alain, 2016; Shaik et al.,2014)

Based on the background and problems that have been described above, it is important to find a solution, given the urgency of the concept of chemical bonds are abstract, at the microscopic level, and require complex spatial understanding. The students’ problem if not sought solutions will have an impact on students’ learning outcomes.

To solve the problem, researchers proposed the development of spatial visually oriented 3D interactive multimedia that can be used as one of the solutions to make teaching and learning activities more active in the absence of restrictions (borderless) so that the obstacles that have appeared can be solved (Damayanti & Dwiningsih, 2017).

The general purpose of this research is to develop 3D interactive multimedia with a viable spatial visual orientation as a learning medium to improve students’ spatial visuals. The specific purpose of the study is to describe the validity of content quality, presentation, and language and also to explain the effectiveness of 3D interactive multimedia reviewed from practicality based on student response and activity.

2. RESEARCH METHOD

2.1 Research Model

This research used Research and Development (R&D) model developed by Sugiyono (Sugiyono, 2017). This study is restricted to limited trial. This research was conducted in accordance with measures called R&D cycle consisting of (1) finding potentials and problems; (2) data collection; (3) product design; (4) validation of product design; (5) revision of product design; (6) limited product trials.

Data processing techniques are carried out by descriptive quantitative conducted by analyzing quantitative data which exist numbers. Descriptive quantitative analysis techniques are used to analyze the assessment data by validators and questionnaire respondents (Septryanesti & Lazulva, 2019).
2.2 Research Instrument

2.2.1 Validity Instrument
Validation stage using a validation sheet instrument. Validation sheet is set up with several criteria and each of that assessed using the Likert Scale (Riduwan, 2007).

Table 1. Likert Scale

| Assessment  | Score |
|-------------|-------|
| Very bad    | 1     |
| Bad         | 2     |
| Moderate    | 3     |
| Good        | 4     |
| Very good   | 5     |

2.2.2 Practicality Instruments based on Student Response Questionnaires
The response questionnaire data was obtained from students' who filled out the response questionnaire instrument in which there were several criteria and then each of that was assessed using a Dichotomy Scale. The response questionnaire has been validated before use in obtaining interactive multimedia practicality data with validity results of 96.67% with a very valid category. The following Dichotomy Scales are presented in Table 2.

Table 2. Dichotomy Scale

| Response | Score |
|----------|-------|
| Yes      | 1     |
| No       | 0     |

2.2.3 Practicality Instruments based on Observation of Student Activities
Observation data obtained from observers who filled the student observation instruments which consist several criteria, then each criteria is assessed using the Dichotomy Scale in Table 2. The observation sheet has been validated before use to observe student activities with validation results of 91.67% in a highly valid category.

The observation sheet has criteria existing student activities that should be carried out in accordance with the learning steps (syntax) in the learning implementation plan. If the majority of students’ do not perform an activity stated in the observation sheet, score "0" will be given on the criteria. Observers provide activity performance scores in the observation sheet in accordance with the reality in the learning process, not based on the results of guessing (subjective) assessments.

2.3 Assessment Procedures

2.3.1 Validation
Validation was carried out by three validators, there are an expert in media, a chemistry expert, and another one is a chemistry teacher. The assessment results of the validators were analyzed to get a percentage. A percentage of the value is obtained using a formula:

\[
(\% \text{Resp}onse) = \frac{F}{N \times I \times R} \times 100
\]

Descriptions:
K = Assessment Percentage
F = Total of respondents' answers
N = Highest Score in Assessment Sheet
I = Total of Questions in Assessment Sheet
R = Total of Respondents

(Riduwan, 2007)

2.3.2 Practicality based on Students’ Response Questionnaires
Students’ response questionnaire data is obtained from students’ who have learned using 3D interactive multimedia. This data was obtained at limited trial stage. The students’ used in the taking were second semester students’ of unesa chemistry education study program as many as eight people who had difficulty in nonpolar polar covalent bonding material based on pretest results conducted before doing learning using 3D interactive multimedia.

The eight respondents had pretest results below the KKM (Kriteria Ketuntasan Minimal/Minimum Completeness Criteria) criteria specified in Permendikbud which is at least 66 with the category "B" (Kemdikbud, 2014). Pretest results obtained are in the range of values 20 to 60 with a category range of "E" to "C+" which means it does not meet the KKM (Kriteria Ketuntasan Minimal/Minimum Completeness Criteria).
Completeness Criteria) criteria value. According to Borg & Gall limited trials can be conducted in one, two, or three schools, using six to twelve test subjects (Heinich, 1979).

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Descriptions:
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2.3.3 Practicality Based on Observation of Student Activities
Observation data obtained from one observer who became observer during the learning process using 3D interactive multimedia. The percentage of its activity is calculated using this following formula:

\[
\text{Percentage} = \frac{\sum \text{Appeared Effectivities}}{\sum \text{Overall Effectivities}} \times 100\%
\]

Activities that appear are activities that are carried out and relevant during the learning process using 3D interactive multimedia. Overall activity is all activities that become the criteria in the observation instrument.

2.4 Analysis of Validation Result
Furthermore, based on the percentage of validation results, students’ response questionnaires, and students’ observations are interpreted that stating the feasibility of interactive multimedia in learning. Interpretation of percentage results follows the criteria in Table 3.

| Percentage (%) | Criteria |
|----------------|----------|
| 0-20           | Very Weak|
| 21-40          | Weak     |
| 41-60          | Enough   |

(Riduwan, 2007)

The 3D interactive multimedia is pronounced good and feasible to use when obtaining percentage of assessment on validity, practicality based on the results of students’ response questionnaires, and practicality based on the observation results of student’s activities at least 61% or strong to very strong categories (Riduwan, 2007).

3. RESULT AND DISCUSSION
This 3D interactive multimedia development research uses Research & Development (R&D) research model by Sugiyono which is limited only until limited product trial (Sugiyono, 2017). The results of the study are described according to the Research and Development (R&D) way as follows:

3.1 Finding Potential and Problems
This research was started by analyzing the problems faced in chemistry learning, especially faced by students'. The results found that students’ have difficulty in learning chemistry due to the concept of chemistry is considered abstract and tiered (Widarti et al., 2018). Abstract concept means that the concept is difficult to learn because critical attributes and variable attributes are difficult to understand and analyze through direct observation using only the human senses (Herron et al., 1977). Abstract concepts in chemistry are materials that require understanding to submicroscopy levels such as atoms, molecules, atomic nuclei, ions, protons, neutrons, chemical bonds (Herron et al., 1977).

3.2 Data Collection
This stage is carried out using instruments that have been prepared for pre-research. Preresearch was conducted at Senior High School 1 Krian by providing questions related to polar and nonpolar covalent bonds, and questionnaires to prove the difficulties faced by students’ due to abstract chemical concept and to know students’ opinions about the learning
that has been done so far. Preresearch results obtained data that 91% of students’ said they had difficulty in polar and nonpolar covalent bonding material. Thus, after testing by working on polar and nonpolar covalent bonding questions, it was found that 69% of students’ received final grades that did not meet the minimum graduation criteria for chemistry subjects. The difficulties faced by students’ include not being able to define polar or nonpolar compounds, classifying polar and nonpolar compounds, not understanding the characteristics of polar compounds or nonpolar compounds.

3.3 Product Design

Product design must be realized in figures or charts (Sugiyono, 2017), therefore at this stage the initial design of the product begins to be drawn up by creating storyboards and flowcharts. Then done interactive multimedia creation. In arranging interactive multimedia design, several researches are needed including:

a. Developing learning indicators and objectives based on Basic Competencies of Curriculum 2013 revision. Because the results of pre-research was known that Senior High School 1 Krian uses curriculum 2013.

b. Searching for introductory videos that serve as motivation for students’.

c. Determining the source of the material according to the indicators and objectives of learning.

d. Determining the 2D and 3D molecular shape of the molecules to be incorporated into interactive multimedia.

e. Determining the direction of the dipolemoment of these molecules.

f. Creating exercise questions for the cognitive abilities of polar and nonpolar covalent bonding materials and spatial visual ability exercises.

g. Making pretest-posttest questions.

h. Creating basic concepts of interactive multimedia, and include all research materials including videos, learning indicators and objectives, learning materials, 3D molecular forms, problem exercises, and discussions about.

Students’ who use interactive multimedia are expected to have more meaningful experience in learning polar and nonpolar covalent bonds while improving their spatial visual abilities. This multimedia is packaged in order that students can learn while driving 3D modeling of polar and nonpolar covalent bonds. Multimedia is equipped with three-dimensional visualization, material explanation and problems related to polar and nonpolar covalent bonds (Nurviandy et al., 2020; Safitri & Dwiningsih, 2019).

According to cognitive learning theory, learning does not simply involve a relationship between stimulus and response, more than that learning involves a very complex thought process. Through learning using interactive multimedia knowledge that obtained can train the visual imagination. The visual imagination is processed deeper into long-term memory through the process of sensing and coding repeatedly (Nur et al., 2008).

Establishing polar and nonpolar covalent bonds (molecular pattern) also requires spatial visual abilities (Wu & Shah, 2004), including the ability to rotate, determining the symmetricality of chemical molecules, and transforming 2D molecular forms into 3D or vice versa (Achuthan et al., 2018; Bodner & McMillen, 1986; Wu & Shah, 2004), so that spatial visuals are the main focus in expanding interactive multimedia following the rotation, symmetry, and interpretation of 3D molecular forms into 2D.

The rotational ability means to rotate the shape of 3D molecules. The ability to imagine the rotation of important 3D molecular shapes is used in determining the pattern of a molecule as well as identification of isomers (Achuthan et al., 2018; Wu & Shah, 2004). The inside of the interactive multimedia in Figure 2 is the “Observing 2” section, this section contains several rotatable 3D molecules so that students’ get the experience of learning molecular rotation.
There is a direction of dipole moments and data on the negativity of each of the constituent elements of the molecule. In this section, students’ can determine the pattern of a molecule based on the data of the literacy, this is because the pattern of a bond is influenced by electrospectiveness, while students’ still do not understand about the election (Widarti et al., 2018). While the dipole moment is a magnitude used to determine the pattern of a molecule, the dipole moment (μ) is the number of vectors from the bonding moment and the moment of the pair of free electrons in a molecule. Molecules are said to be polar if they μ > 0 or μ ≠ 0 and are said to be nonpolar if they have μ = 0 (Effendy, 2004).

The ability to identify symmetry compounds is very necessary in determining the pattern of a compound, because nonpolar molecules have one of the characteristics of symmetry molecules (Effendy, 2004; Kumar, 2012). Then to provide a good understanding of symmetry required spatial visual abilities (Bodner & McMillen, 1986).

The ability to interpret 3D molecules into 2D is indispensable in solving chemical problems especially in determining molecular polarity (Wu & Shah, 2004). In the chemistry learning of spatial visual ability interpretation of 2D form to 3D form, the goal is to exercising students’ imagination to create 3D models of 2D that have existed in the questions proposed in chemistry learning generally, so mentally students’ can describe the 3D form then can mention the molecular form of the molecular formula as well as from the structure formula proposed on the chemical question. Instead students’ can also determine the structure formula of a molecule after the student gets 3D form information from the molecule. This ability also serves to decide the symmetry of a molecule by looking at the shape of its molecules.

This interpretation ability arises when students’ fill out LKPD (Lembar Kerja Peserta Didik/Student Worksheets) interactive supporting multimedia. In addition, LKPD serves as a sheet of student observations. Students’ can observe the 3D form of molecules from interactive multimedia, then interpret it to a 2D form or structure formula, the interpretation is written on a supporting LKPD or observation sheet. The following examples of interpretations made by students’ are presented in Figure 4.

In addition, this interactive multimedia provides learning experience up to the submicroscopy level. Figure 5 shows the macroscopic level, that practicum videos are presented in the laboratory regarding differences in solubility of polar and nonpolar compounds. Macroscopic levels are chemical phenomena that can be observed by the human senses (Treagust et al., 2003).

Figure 2. Experience Learning Spatial Visual Ability Rotates in Interactive Multimedia

Figure 3. Experience Learning of Spatial Visual Symmetry Capabilities in Interactive Multimedia.

Figure 4. Experience Learning of Spatial Visual Ability In Interpreting 3D Form Becomes 2
The Development of 3D Interactive Multimedia Oriented Spatial Visually on Polar and Nonpolar Covalent Bonding Materials

3.4 Design Validation
Revised interactive multimedia results will be validated. Validation results are displayed in Table 4 as follows:

| No | Assessment Aspect | Presentation and Criteria |
|----|-------------------|--------------------------|
| 1. | **Content Validation** |  |
|    | Material Aspect | 91.11% (Strongly Valid) |
| 2. | **Construct Validation** |  |
|    | Presentation Aspect | 92.50% (Strongly Valid) |
|    | Language Aspect | 81.11% (Strongly Valid) |

3.4.1 Content Validation
Assessment of the validity of content based on aspect of the suitability of the selected material with the curriculum (Ilyasa & Dwiningsih, 2019). Validation results and validated aspect are presented in Figure 6.

![Figure 6. Diagram Result of Content Validation](image)

Descriptions:
A = Suitability of materials with Curriculum
B = Learning indicators
C = Effectiveness of students’ activities
D = Suitability of exercises with the indicators
E = Suitability of molecules to exercise spatial visual abilities

Overall, the validity of content for 3D interactive multimedia on polar and nonpolar covalent bonding materials to improve students’ spatial visual abilities was 86.81% which was categorized as highly valid.

3.4.2 Construct Validation
The validity of the construction consists of two aspects namely the presentation aspect and the language aspect (Ilyasa & Dwiningsih, 2019). The results of the validity of the construct are described in Figure 7.

![Figure 7. Percentage Diagram Results of Construct Validation](image)
3.4.2.1 Presentation Aspect

The presentation aspect of the assessment is focused on interactive multimedia display so that the harmony and function of interactive multimedia components runs well each other. The presentation aspect consists of several criteria. The criteria are described along with the percentage of values obtained in Figure 8:

![Figure 8. Diagram Results of The Assessment of Construct Validation in Presentation Aspect](image)

| Criteria | Percentage |
|----------|------------|
| A (Design selection, text size and color) | 93.33% |
| B (Matching text colors, backgrounds images, molecular shapes, and buttons) | 80.00% |
| C (The provided button can function properly) | 86.67% |
| D (The shape of the molecules presented is appropriate) | 80.00% |
| E (The text and sentences presented are well readable) | 86.67% |
| F (The text of the translate in the video is clearly presented) | 73.33% |
| G (The suitability of the molecular shape with the text is good) | 80.00% |
| H (Image suitability with text is good) | 100.00% |

3.4.2.2 Language Aspect

The language aspect of the assessment is focused on grammar in interactive multimedia that matches Enhanced Spelling and the writing of superscript and subscript chemistry. The criteria for language aspect is described along with the percentage of values obtained in Figure 9.

![Figure 9. Diagram Results of The Assessment of Construct Validation in Language Aspect](image)

| Language Aspect | Percentage |
|-----------------|------------|
| A (Media developed using grammar and spelling in accordance with good and correct language rules) | 93.33% |
| B (Media developed using easy-to-understand language) | 93.33% |
| C (Language used between paragraphs and sentences) | 86.67% |
| D (Use appropriate and correct terms and punctuation) | 80.00% |
| E (Using the right chemical symbols) | 80.00% |
| F (The Indonesian translation in the video works properly) | 73.33% |

Overall, the construction validity results for 3D interactive multimedia on polar and nonpolar covalent bonding materials to improve students’ spatial visual abilities were 91.11% categorized as highly valid. So that the following 3D interactive multimedia developed spatial visual oriented on nonpolar covalent bonding material is valid based on material aspect, presentation aspect, and language aspect.

3.5 Revise Design

Products that have been validated by experts, it will be found deficiencies and weaknesses based on input from validators. These weaknesses can be reduced by improving the resistance of design revision research (Sugiyono, 2017).

Revisions are carried out in the section observing 1 in 3D interactive multimedia, revisions are carried out in the direction of the dipole moment. The initial design of the dipole moment direction appears when the
electronegativity of the two molecular constituent atoms is similar. However, when the electronegativity of the two molecular constituent atoms is similar, it should not have a dipole or $\mu = 0$ (Effendy, 2004).

3.6 Product Trial
The product trial conducted was limited trial with eight students of the second semester of chemistry education program in Unesa as the research subjects. This product trial aims to obtain interactive multimedia practicality data. The practicality of interactive multimedia is measured from the results of the dissemination of student response questionnaires after using interactive multimedia and observation sheets of learning implementation because students are the main users of interactive multimedia, so that the students who assess the level of practicality are students’ (Ulya, H., 2017).

3.6.1 Practicality Based on Student Response Questionnaire Results
Students’ are given questionnaires containing questions related to the criteria for students’ understanding of the material, ease of use, clarity of media, language. The results of the students’ response questionnaire are presented in Figure 10.

![Graph of Practicality Based on Student Response Questionnaires](image)

**Figure 10. Graph of Practicality Based on Student Response Questionnaires**

**Descriptions:**
A = Students’ understanding of the materials
B = Ease of use
C = Obviousness media
D = Language

On the criteria of students’ understanding of the material, it obtains a percentage of 83.33% in a very strong category, it can be concluded that the material presented in the media is very well understood students’. On the ease of use criteria, it gets a percentage of 65.00% in the practical category. This means that interactive multimedia can be used by students’ well.

In the criteria of media clarity in which there is clarity of description of observation steps using interactive multimedia, clarity of letter use, use of background colour that is compatible with letters, and aspect of multimedia graphics, it raises a percentage of 87.50% with a very practical category. This means that the graphical or interactive multimedia presentation is presented very well. In the linguistic criteria in it there is an assessment of the sentence order used in interactive multimedia in accordance with Enhanced Spelling, chemical formula writing, and the language demand used gets a percentage of 95.83% with a very practical category. This means that the language used in interactive multimedia is well presented.

The average students’ response questionnaire is 82.92% with a very practical category. In the criteria of ease of use, it still does not get results that are not maximum because students’ as users or advice from validators stated the need for a user manual so the use of media will be easier to understand.

3.6.2 Practicality Based on Observations of Student Activities
The observation results of students’ activities aim to find out the activities of students’ during limited trials. Activity is observed by observers. Observations of student activities are presented in Figure 11.

![Graph of student activity observation results](image)

**Figure 11. Graph of student activity observation results**
Relevant activities during this learning include students’ reading materials presented in interactive multimedia, students’ observing videos of phenomena presented, students’ making observations both observing 1 and observing 2, and students’ trying to practice the questions contained in interactive multimedia.

Based on the results obtained the percentage of relevant student activities is 94.74% with a very practical category. This means that students' during the learning using interactive multimedia take place to conduct relevant activities in accordance with the criteria in the observation assessment. Activities that are less relevant in using interactive multimedia are the majority of students' do not read the learning objectives that have been stated so do not understand the learning targets that must be achieved while using interactive multimedia, also skip in reading the material already stated in the interactive multimedia.

4. CONCLUSION

Based on the results of analysis and discussion on development research, it is declared worthy of validity aspect, and practicality can be concluded that each validation indicator in 3D interactive multimedia obtains an assessment of validators with a mode (Mo) of at least 4 in the range of score 1-5 and percentage of agreement (R) values between validators above 75%. 3D interactive multimedia is declared eligible for practicality because in each indicator it obtains an assessment from the user's student with a minimum mode (Mo) of 4 in the score range of 1-5 and a percentage of agreement (R) value between students' above 75%.
The Development of 3D Interactive Multimedia Oriented Spatial Visually on Polar and Nonpolar Covalent Bonding Materials

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