JTK: Jurnal Tadris Kimiya 5, 2 (December 2020): 153-165
Website: http://journal.uinsgd.ac.id/index.php/tadris-kimiya/index
ISSN 2527-9637 **(online) ISSN** 2527-6816 **(print)**

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

Ilo Isaloka[1] and Kusumawati Dwiningsih[1*]
[1]Department of Chemistry, Universitas Negeri Surabaya, Jl. Ketintang, Surabaya, 60231, Indonesia
[*]E-mail: kusumawatidwiningsih@unesa.ac.id

Received: 07 September 2020; Accepted: 26 November 2020; Published: 31 December 2020

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

DOI: http://doi.org/10.15575/jtk.v5i2.8688

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). The 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.

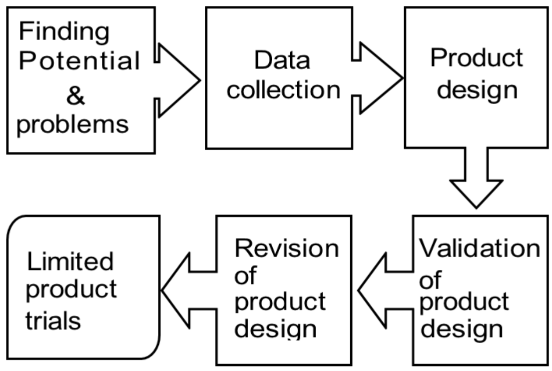


Figure 1. Research and Development Measures to be used modifications (Sugiyono, 2017)

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

Validity 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

Repons	Score
Yes	1
No	0

(Riduwan, 2007)

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:

$$(\%)Respons = \frac{F}{N \times I \times R} \times 100$$

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) 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).

Then the student response results are analyzed to get a percentage. A percentage of the value is obtained using a formula:

$$(\%)Respons = \frac{F}{N \times I \times R} \times 100$$

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)

2.3.3 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:

$$(\%)Activities = \frac{\Sigma \text{ Appeared Effectivities}}{\Sigma \text{ Overall Effectivities}}\ x\ 100\%$$

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.

Table 3. The Percentage of Interpretation Criteria

Percentage (%)	Criteria
0-20	Very Weak
21-40	Weak
41-60	Enough
61-80	Strong
81-100	Very strong

(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 threedimensional 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.

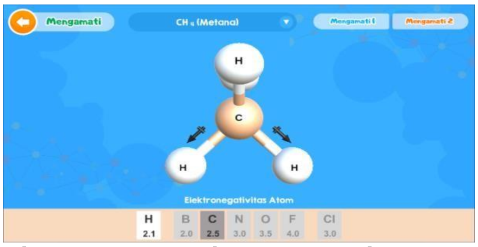


Figure 2. Experience Learning Spatial Visual Ability Rotates in Interactive Multimedia

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 $\mu > 0$ or $\mu \neq 0$ and are said to be nonpolar if they have $\mu = 0$ (Effendy, 2004).

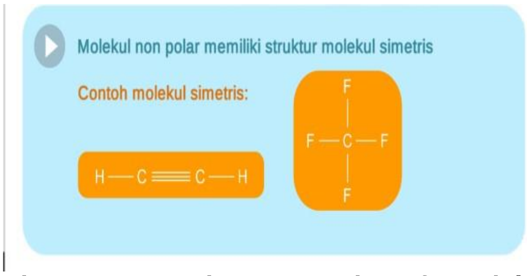


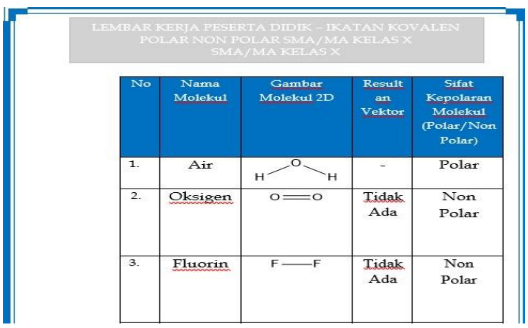
Figure 3. Experience Learning of Spatial Visual Symmetry Capabilities in Interactive Multimedia.

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).



LEMBAR KERJA PESERTA DIDIK – IKATAN KOVALEN POLAR NON POLAR SMA/MA KELAS X SMA/MA KELAS X

No	Nama Molekul	Gambar Molekul 2D	Resultan Vektor	Sifat Kepolaran Molekul (Polar/Non Polar)
1.	Air	H–O–H	-	Polar
2.	Oksigen	O=O	Tidak Ada	Non Polar
3.	Fluorin	F—F	Tidak Ada	Non Polar

Figure 4. Experience Learning of Spatial Visual Ability In Interpreting 3D Form Becomes 2

Figure 5. Learning Experience of Macroscopic Representation

Students' can observe the solubility of polar and nonpolar compounds by the senses of human, which does not require computer description. The essence of the video is to show that polar compounds will dissolve in polar solvent and nonpolar compounds will dissolve in nonpolar solvents (Effendy, 2004).

Based on material particle theory, submicroscopy representation used to explain chemical phenomena such as particle movement at the level of electrons, molecules, and atoms (Mujakir, 2018). At level of interactive multimedia submicroscopy representation, it presents a description of the shape of a 3D-shaped molecule that can be rotated and the influence of electronegativity on the moment of dipolee, the moment of dipolee is a magnitude used to determine the pattern of a molecule. The experience of submicroscopy representation can be found in the "Observing 2" section in interactive multimedia or in Figure 2 above.

3.4 Design Validation

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

Table 4. Validation Results

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.
Following:

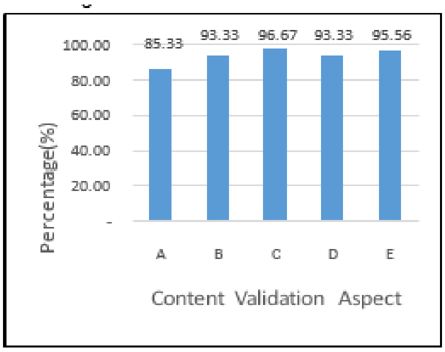


Figure 6. Diagram Result of Content Validation

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.

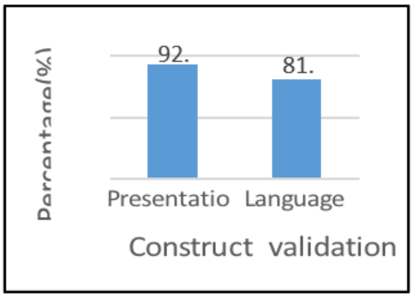


Figure 7. Percentage Diagram Results of Construct Validation

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:

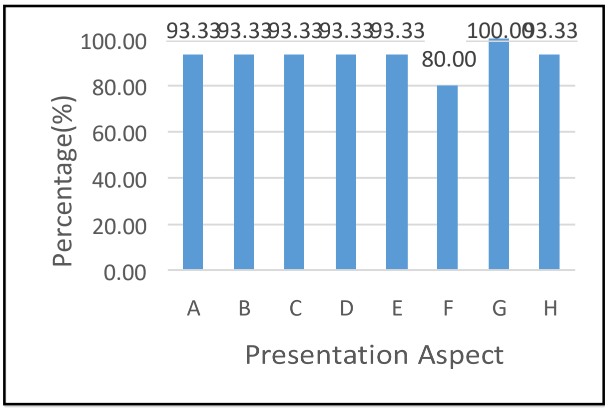


Figure 8. Diagram Results of The Assessment of Construct Validation In Presentation Aspect

Descriptions:
A = Design selection, text size and color are already unified
B = Matching text colors, backgrounds images, molecular shapes, and buttons
C = The provided button can function properly
D = The shape of the molecules presented is appropriate
E = The text and sentences presented are well readable
F = The text of the translate in the video is clearly presented
G = The suitability of the molecular shape with the text is good
H = Image suitability with text is good

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.

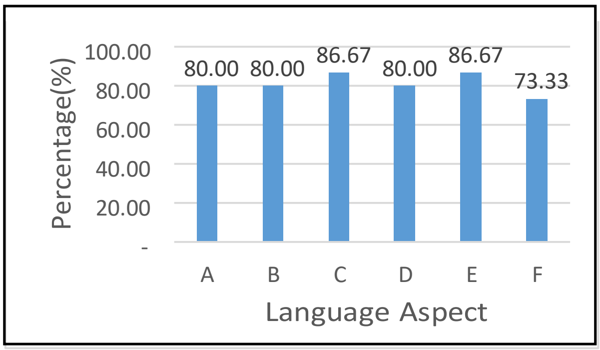


Figure 9. Diagram Results of The Assessment of Construct Validation In Language Aspect

Descriptions:
A = Media developed using grammar and spelling in accordance with good and correct language rules
B = Media developed using easy-to-understand language
C = Language used between paragraphs and sentences
D = Use appropriate and correct terms and punctuation
E = Using the right chemical symbols
F = The Indonesian translation in the video works properly

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 polar 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 μ = 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.

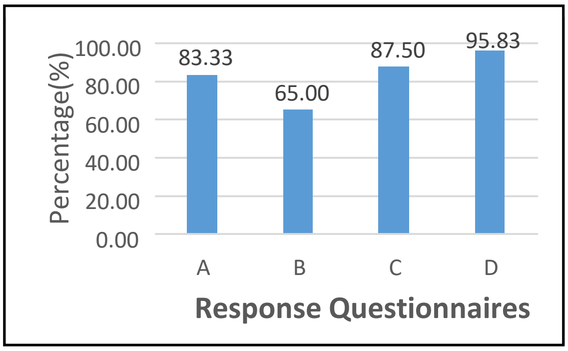


Figure 10. Graph of Practicality Based on Student Response Questionnaires

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.

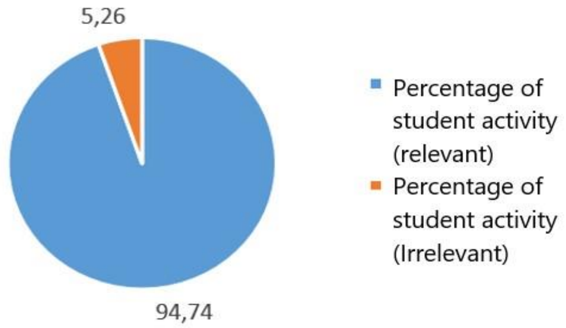


Figure 11. Graph of student activity observation results

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%.

REFERENCES

Abraham, M., Varghese, V., & Tang, H. (2010). Using molecular representations to aid student understanding of stereochemical concepts. *Journal of Chemical Education*, *87*(12),1425–1429. https://doi.org/10.1021/ed100497f

Achuthan, K., Kolil, V. K., & Diwakar, S. (2018). Using Virtual Laboratories in Chemistry Classrooms as Interactive Tools Towards Modifying Alternate Conceptions in Molecular Symmetry. *Education and Information Technologies*, *23*(6), 2499–2515. https://doi.org/10.1007/s10639-018-9727-1

Ahvan, Y. R., & Pour, H. Z. (2016). The Correlation of Multiple Intelligences for the Achievements of Secondary Students'. *Educational Research and Reviews*, *11*(4), 141–145. https://doi.org/10.5897/err2015.2532

Anggriawan, B., Effendy, & Budiasih, E. (2017). Kemampuan Spasial dan Kaitannya dengan Pemahaman Mahasiswa terhadap Materi Simetri. *Jurnal Pendidikan: Teori, Penelitian, dan Pengembangan*, *2*(12), 1612–1619. http://dx.doi.org/10.17977/jptpp.v2i12.10299

Barnea, N. (2000). Teaching and Learning about Chemistry and Modelling with a Computer managed Modelling. In *Developing Models in Science Education*, 307–323. https://doi.org/10.1007/978-94-010-0876-1_16

Bende, D., Wagner, F. R., & Grin, Y. (2015). 8-N Rule and Chemical Bonding in Main-Group MgAgAs-type Compounds. *Inorganic Chemistry*, *54*(8), 3970–3978. https://doi.org/10.1021/acs.inorgchem.5b00135

Bergqvist, A., Drechsler, M., De Jong, O., & Rundgren, S. N. C. (2013). Representations of Chemical Bonding Models in School Textbooks-Help or Hindrance for Understanding?. *Chemistry Education Research and Practice*, *14*(4), 589–606. https://doi.org/10.1039/c3rp20159g

Bodner, G. M., & McMillen, T. L. B. (1986). Cognitive Restructuring as an Early Stage in Problem Solving. *Journal of Research in Science Teaching*, *23*(8), 727–737. https://doi.org/10.1002/tea.3660230807

Damayanti, D., & Dwiningsih, K. (2017). Pengembangan Perangkat Pembelajaran Berorientasi Blended Learning pada Materi Sistem Periodik Unsur Kelas X SMA (Development of learning device oriented blended learning on periodic table material for tenth grade senior high school). *UNESA Journal of Chemistry Education*, *6*(1), 16–23.

Effendy. (2004). *Ikatan Kimia*. Malang: Indonesian Academic Publishing.

Heinich, R. (1979). *Educating All Handicapped Children*. New Jersey: Educational Technology Publications.

Herron, J. D., Cantu, L. L., Ward, R., & Srinivasan, V. (1977). Problems Associated with Concept Analysis. *Science Education*, *61*(2), 185–199. https://doi.org/10.1002/sce.3730610210

Ilyasa, D. G., & Dwiningsih, K. (2019). The Validity of Interactive Multimedia on Ionic Bond Material. *JCER (Journal of Chemistry Education Research)*, *3*(2), 51-57. https://doi.org/10.26740/jcer.v3n2.p51-57

Jiang, J., Zhao, Y., & Yaghi, O. M. (2016). Covalent Chemistry beyond Molecules. *Journal of the American Chemical Society*, *138*(10), 3255–3265. https://doi.org/10.1021/jacs.5b10666

Kemdikbud. (2014). *Permendikbud No.104 Tahun 2014 Tentang Penilaian Hasil Belajar oleh Pendidik pada Pendidikan Dasar dan Menengah*. Jakarta: Depdiknas.

Kumar, A. (2012). *Numerical Chemistry*. New York: McGraw-Hill.

Levy Nahum, T., Mamlok- Naaman, R., Hofstein, A., & Taber, K. S. (2010). Teaching and Learning the Concept of Chemical Bonding. *Studies in Science Education*, *46*(2), 179–207. https://doi.org/10.1080/03057267.2010.504548

Mohamed-Salah, B., & Alain, D. (2016). To What Degree Does Handling Concrete Molecular Models Promote The Ability to Translate and Coordinate Between 2D And 3D Molecular Structure Representations? A Case Study With Algerian Students'. *Chemistry Education Research and Practice*, *17*(4), 862–877. https://doi.org/10.1039/c5rp00180c

Mujakir, M. (2018). Pemanfaatan Bahan Ajar Berdasarkan Multi Level Representasi Untuk Melatih Kemampuan Siswa Menyelesaikan Masalah Kimia Larutan. *Lantanida Journal*, *5*(2), 183. https://doi.org/10.22373/lj.v5i2.2839

Nur, M., Wikandari, P. R., & Sugiarto, B. (2008). *Teori-teori Pembelajaran Kognitif*. Surabaya: PSMS Unesa.

Nurviandy, I., Dwiningsih, K., Habibi, A. R., & Akbar, A. F. (2019, December). Validity of Interactive Multimedia with 3D Visualization to Practice the Spatial Visual Intelligence of Class X High School Students' on Metallic Bonding Materials. *National Seminar on Chemistry 2019 (SNK-19)*, *1*, 140–144. Atlantis Press. https://doi.org/10.2991/snk-19.2019.33

Plomp, T., & Nieveen, N. (2010). An Introduction to Educational Design Research. *Proceedings of the Seminar Conducted at the East China Normal University, Shanghai (PR China)*, *November 23-26*, 2007. Stiching Leerplan Ontwikkeling (SLO).

Riduwan. (2007). *Skala Pengukuran Variabel-Variabel Penelitian*. Bandung: Alfabeta.

Safitri, N. Y., & Dwiningsih, K. (2019). Development Interactive Multimedia Using 3D Virtual Modelling on Intermolecular Forces Matter. *International Journal of Chemistry Education Research*, *3*(3), 17–25. https://doi.org/10.20885/ijcer.vol4.iss1.art3

Septryanesti, N., & Lazulva, L. (2019). Desain Dan Uji Coba E-Modul Pembelajaran Kimia Berbasis Blog pada Materi Hidrokarbon. *JTK (Jurnal Tadris Kimiya)*, *4*(2), 202–215. https://doi.org/10.15575/jtk.v4i2.5659

Shaik, S., Danovich, D., Wu, W., & Hiberty, P. C. (2014). The Valence Bond Perspective of the Chemical Bond. *The Chemical Bond: Fundamental Aspect of Chemical Bonding*, *9783527333*, 159–198. https://doi.org/10.1002/9783527664696.ch5

Sugiyono. (2017). *Metode Penelitian Kuantitatif, Kualitatif dan R&D*. Bandung: Alfabeta.

Taber, K. S., Tsaparlis, G., & Nakiboğlu, C. (2012). Student Conceptions of Ionic Bonding: Patterns of Thinking Across Three European Contexts. *International Journal of Science Education*, *34*(18), 2843–2873. https://doi.org/10.1080/09500693.2012.656150

Tasker, R. (2014). Research into Practice: Visualising the Molecular World for a Deep Understanding of Chemistry. *Teaching Science*, *60*(2), 16–27.

Treagust, D. F., Chittleborough, G., & Mamiala, T. L. (2003). The Role of Submicroscopic and Symbolic Representations in Chemical Explanations. *International Journal of Science Education*, *25*(11), 1353–1368. https://doi.org/10.1080/0950069032000070306

Tuvi-Arad, I., & Gorsky, P. (2007). New Visualization Tools for Learning Molecular Symmetry: A Preliminary Evaluation. *Chemistry Education Research and Practice*, *8*(1), 61–72. https://doi.org/10.1039/B6RP90020H

Ulya, H. (2017). Pengembangan Modul Kimia Berbasis Problem Solving pada Materi Asam Basa Arrhenius. *Jurnal Pendidikan dan Pembelajaran Kimia*, *7*(1), 129–141.

Vrabec, M., & Prokša, M. (2016). Identifying Misconceptions Related to Chemical Bonding Concepts in the Slovak School System Using the Bonding Representations Inventory as a Diagnostic Tool. *Journal of Chemical Education*, *93*(8), 1364–1370. https://doi.org/10.1021/acs.jchemed.5b00953

Widarti, H. R., Safitri, A. F., & Sukarianingsih, D. (2018). Identifikasi Pemahaman Konsep Ikatan Kimia. *J-PEK (Jurnal Pembelajaran Kimia)*, *3*(1), 41–50. https://doi.org/10.17977/um026v3i12018p041

Wu, H. K., & Shah, P. (2004). Exploring Visuospatial Thinking in Chemistry Learning. *Science Education*, *88*(3), 465–492. https://doi.org/10.1002/sce.10126

Zhou, S., Sherpa, S. D., Hess, D. W., & Bongiorno, A. (2014). Chemical Bonding of Partially Fluorinated Graphene. *Journal of Physical Chemistry C*, *118*(45), 26402–26408. https://doi.org/10.1021/jp508965q