Make it real: Simulation of 3D molecules using Augmented Reality in chemical bonding topic

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Abstract. The chemical bonding is one of the crucial topics in chemistry as it becomes a basic concept to comprehend other topics. Unfortunately, it is difficult for students to understand because it is at the submicroscopic level. This study proposes a way to comprehend that topic by developing a simulation of 3D molecules using Augmented Reality (AR). The data was collected by questionnaire. This study was used ADDIE procedure to develop the product. From the results of this study, it can be concluded that the Augmented Reality learning media has a very good quality and is worthy of being used as a supporting media in chemical learning activities in the chemical bond topic.

1. Introduction

Chemistry cannot be separated from three levels of representation, namely macroscopic, submicroscopic, and symbolic [1]. One of the most difficult for chemistry learners’ is linking between the macroscopic world that they can see with the submicroscopic world [2]. Some basic concepts of chemistry are at the submicroscopic level, one of them is the chemical bonding material. Chemical bonds are one of the crucial and important material to be understood by students [3, 4]. A misconception of the basic concepts (i.e. chemical bonding) learned in secondary schools will carry over to the university level or further learning of chemistry [5, 6]. There have been immensely numerous researches carried out starting from the identification of students' difficulties [7] to the ability of teachers in delivering material [3], yet up to now misconceptions in learning chemistry, especially the topic of chemical bonds are still occurred [8].

In Indonesia, Augmented Reality is actually not a new technology, but its name is sticking out today when the Pokemon Go game exploded on the market. The use of Augmented Reality in Indonesia is currently more in the field of entertainment and games. Meanwhile, in other countries, Augmented Reality is also used in the field of research and development as a learning media. For instance, in India, Augmented Reality in chemistry learning, students can understand the spatial relationship between molecules in 3 dimensions efficiently [9]. In addition, Augmented Reality has a significant additional learning effect as a computer-assisted learning tool and is considered more effective for low achievers than high achievers [10]. However, in Indonesia, there is still not sufficient research and development on Augmented Reality in the field of education. The development of Augmented Reality is thriving in the field of education, especially at the university level on the topic of molecular [11]. Moreover, learning chemistry using animation at the submicroscopic level can identify misconceptions and provide students better understanding than learning only on paper [12]. The purpose of this study is to design
and develop the Augmented Reality learning media on chemical bonding material for 10-grade students. The research questions were addressed in this paper were: (1) What are the challenges in chemical bonding material for 10-grade students? (2) How to develop the Augmented Reality learning media on chemical bonding material for 10-grade students? (3) How is the feasibility of the Augmented Reality learning media developed based on experts, teachers and students assessment?

2. Methodology

2.1. Participant
This study involved 3 material and language experts, 3 media experts, 50 students, and 3 teachers. The experts are lecturers at Universitas Negeri Jakarta. While teachers and students are from two public schools in Jakarta as the users of the Augmented Reality learning media.

2.2. Instrument and procedure
This study employed a survey research design [13]. The research team used paper-based questionnaires which has Likert-type scale to collect the data from participants. There are four types of questionnaires; First, a questionnaire for students at the beginning of the research to find out the challenges in learning chemical bonds material for 10-grade students. Second, there are three other questionnaires for experts, teachers, and students to assess the Augmented Reality learning media feasibility.

The steps for developing Augmented Reality learning media on chemical bonding materials include five steps of the ADDIE model, which are analysing, designing, developing, implementing, and evaluating stages [14, 15]. At the analysis stage in this study, involving needs analysis, curriculum analysis and analysis of the characteristics of students. This is to find out the problems that occur in learning chemistry, particularly on chemical bond material. The results of the analysis phase serve as the basis for making Augmented Reality learning media. at the designing stage do compiling material, making a flowchart, and making storyboards. In addition, at this stage, a research instrument was also developed for the feasibility assessment of the Augmented Reality learning media developed. At the stage of development, flowchart, material, storyboards that have been compiled were embedded into media. To develop Augmented Reality learning media, Unity3D 2017.3.0f3 software is used as the main software, while Microsoft PowerPoint 2010, the 2015 Adobe Illustrator CC and Adobe Photoshop CS4 as supporting software. In the design and development stages, evaluations were also carried out by experts, so that the developed media received corrections and inputs to correct a misconception in learning. In the implementation stage, learning media were declared worthy of trial by material and language expert lecturers and media expert lecturers, tested to students in two different schools and one chemistry teacher. Furthermore, at the evaluation stage, formative evaluation is carried out, because this type of evaluation relates to the stages of development research to improve the products produced. The evaluation was carried out at each stage of development by researchers with the aid of experts. The evaluation is in the form of input and revision at the each stage of design and development.

3. Result and discussion

3.1. The challenges in learning chemical bonding material for 10-grade students
Needs analysis is done by distributing questionnaires to 33 10-grade students in one of the public high schools in Jakarta who has studied chemical bonding material. In addition, a questionnaire was also given to two chemistry teachers. The result is that 54.5% of students stated that chemical bonding material is a difficult material. According to students, the difficulty of the chemical bond material is determining the type of chemical bond that occurs, because these chemical bonds are abstract material and extremely full of memorization. The alternative used by students to overcome the difficulties of understanding chemical bonding material is by multiplying reading books, increasing practice questions, utilizing smartphones as a source of learning and watching learning videos. This is similar to what the
teacher said that chemical bonding material is difficult because the material is extremely abstract for students.

3.2. Design and develop the Augmented Reality learning media
At this stage, chemical bond material is produced which will be inserted in Augmented Reality learning media. In addition, a complete picture of the media that will be created is produced at this stage. Starting from the display design, image, animation, video, features, and flow of media usage. At this stage, media assessment questionnaires were produced which was validated by experts.

3.3. The feasibility of the Augmented Reality learning media developed

3.3.1. The Augmented Reality learning media assessment by the experts. Based on the results of media validation conducted by three chemistry lecturers, learning media were declared valid with revisions according to their input and suggestions. Data from the feasibility test questionnaire by material and language expert lecturers are presented in table 1.

| No | Aspect | Items | Average Percentage | Criteria |
|----|--------|-------|---------------------|----------|
| 1  | Content validity | 1, 2 and 3 | 89% | Very good |
| 2  | Concept conformity | 4 and 5 | 88% | Very good |
| 3  | Language compatibility | 6, 7, 8, 9, 10, 11 and 12 | 90% | Very good |
|    | **Overall Average Media Rating** |       | **89%** | **Very good** |

In addition, validation was carried out by media experts. Based on the results of media validation, Augmented Reality learning media is declared valid with revisions according to input and suggestions. Revised aspects, particularly in terms of media design. Data from the feasibility test questionnaire by media expert lecturers are presented in table 2.

| No | Aspect | Item(s) | Average Percentage | Criteria |
|----|--------|---------|---------------------|----------|
| 1  | Easy to see | 1, 2, 3 and 4 | 90% | Very good |
| 2  | Attractive | 5 and 6 | 96% | Very good |
| 3  | Simple | 7 and 8 | 100% | Very good |
| 4  | Usefulness | 9 | 100% | Very good |
| 5  | Valid and can be accounted for | 10, 11 and 12 | 94% | Very good |
| 6  | Design | 13, 14, 15 and 16 | 96% | Very good |
|    | **Overall Average Media Rating** |       | **96%** | **Very good** |

3.3.2. The Augmented Reality learning media assessment by the teachers. Based on the results of teacher assessment in table 3, it can be seen that the average assessment of the Augmented Reality learning media as a whole is 90% with very good criteria indicating that the teacher can accept the use of Augmented Reality learning media as a learning medium that can support chemistry learning on chemical bonding topic.

| No | Aspect | Item(s) | Average Percentage | Criteria |
|----|--------|---------|---------------------|----------|
| 1  | Content validity | 1, 2 and 3 | 92% | Very good |
| 2  | Concept conformity | 4 and 5 | 88% | Very good |
| 3  | Easy to see | 6, 7 and 8 | 86% | Very good |
| 4  | Attractive | 9 and 10 | 96% | Very good |
| 5  | Simple | 11 and 12 | 92% | Very good |
| 6  | Usefulness | 13 | 92% | Very good |
| 7  | Valid and can be accounted for | 14, 15 and 16 | 89% | Very good |
| 8  | Design | 17, 18, 19 and 20 | 85% | Very good |
|    | **Overall Average Media Rating** |       | **90%** | **Very good** |
3.3.3. The Augmented Reality learning media assessment by the students. After the media is validated by experts and teachers, the media is tested on students to find out whether Augmented Reality learning media can be used by students to support their understanding of chemical bonding topic. The results of the test produced an average percentage in each aspect worth 90% which can be seen in table 4. The data shows that the media developed is very good and can be used to support the learning process on the chemical bonding topic.

Table 4. Feasibility test results by the students.

| No | Aspect      | Item(s)          | Average Percentage | Criteria     |
|----|-------------|------------------|--------------------|--------------|
| 1  | Content validity | 1 and 2          | 91%                | Very good    |
| 2  | Easy to see   | 3,4,5 and 6      | 92%                | Very good    |
| 3  | Attractive    | 7 and 8          | 91%                | Very good    |
| 4  | Simple        | 9, 10, 11 and 12 | 88%                | Very good    |
| 5  | Design        | 13, 14, 15 and 16| 89%                | Very good    |
|    | Overall Average Media Rating |                | 90%                | Very good    |

The following figures are the final results of Augmented Reality media that have been developed based on the assessment and suggestions of experts, teachers, and students which can be seen in figure 1-4, including: screenshot of display on the loading menu (figure 1), display on the application’s main menu (figure 2), display starts the AR camera (figure 3), and simulation of 3D molecules on ionic bonds (figure 4).

4. Conclusion
Based on the results of the research described above, the Augmented Reality learning media developed has a good quality, viewed from the results of the appraisal by material and language experts as well as appraisal by media experts and trials conducted on teachers and students. Thus, it can be concluded that
this study produced Augmented Reality learning media on the material of chemical bonds that are worthy for being used as learning media to support the chemistry learning process.

References
[1] Treagust D F, Chittleborough G and Mamiala T L 2003 The role of submicroscopic and symbolic representations in chemical explanations Int. J. Sci. Educ. 25 1353–68
[2] Tümay H 2016 Reconsidering learning difficulties and misconceptions in chemistry: emergence in chemistry and its implications for chemical education Chem. Educ. Res. Pract. 17 229–45
[3] Bergqvist A, Drechsler M and Chang Rundgren S N 2016 Upper Secondary Teachers’ Knowledge for Teaching Chemical Bonding Models Int. J. Sci. Educ. 38 298–318
[4] Dhindsa H S and Treagust D F 2014 Prospective pedagogy for teaching chemical bonding for smart and sustainable learning Chem. Educ. Res. Pr. 15 435–46
[5] Erman E 2017 Factors contributing to students’ misconceptions in learning covalent bonds J. Res. Sci. Teach. 54 520–37
[6] Luxford C J and Bretz S L 2014 Development of the bonding representations inventory to identify student misconceptions about covalent and ionic bonding representations J. Chem. Educ. 91 312–20
[7] Kim-Chwee Daniel Tan A, Treagust D F and Daniel Tan K-C 1999 Title Evaluating students’ understanding of chemical bonding Evaluating students’ understanding of chemical bonding Student difficulties with chemical bonding Source Sch. Sci. Rev. Sch. Sci. Rev. 81 75–84
[8] Taskin V and Bernholt S 2014 Students’ Understanding of Chemical Formulae: A review of empirical research Int. J. Sci. Educ. 36 157–85
[9] Singhal S 2012 Augmented Chemistry : Interactive Education System 49 1–5
[10] Cai S, Wang X and Chiang F 2014 A case study of Augmented Reality simulation system application in a chemistry course Comput. Human Behav. 37 31–40
[11] Irwansyah F S, Yusuf Y M, Farida I and Ramdhani M A 2018 Augmented Reality (AR) Technology on the Android Operating System in Chemistry Learning IOP Conf. Ser. Mater. Sci. Eng. 288 012068
[12] Akaygun S 2016 Is the oxygen atom static or dynamic? The effect of generating animations on students’ mental models of atomic structure Chem. Educ. Res. Pr. 17 788–807
[13] Cresswell J W 2012 Educational Research Planning, Conducting, and Evaluating Quantitative and Qualitative Research (Boston, MA: Pearson Education, Inc.)
[14] Branch R M 2009 Instructional Design: The ADDIE Approach vol 722 (Boston, MA: Springer US)
[15] Saidin N F, Dayana N, Halim A, Yahaya N, Chemical Á and Visualization Á A Á 2016 Proceedings of the 2nd International Colloquium of Art and Design Education Research (i-CADER 2015) Proc. 2nd Int. Colloq. Art Des. Educ. Res. (i-CADER 2015)