Development of Augmented Reality-Based Online Learning Media to Improve Students' Mental Models on the Topic of Environmental Pollution

Wildan, Saprizal Hadisaputra, Lalu Rudyat Telly Savalas, Baiq Dwi Laksmiwati, and Supriadi(✉)

Department of Chemistry Education, Faculty of Teacher Training and Education, University of Mataram, Mataram, Indonesia
supriadi_fkip@unram.ac.id

Abstract. The purpose of this study was to develop online learning based on augmented reality (AR) technology related to environmental pollution and its effect on the mental model of students of the Chemistry Education Study Program, FKIP University of Mataram. The results of this study are expected as a first step to produce graduates who have a complete mental model, so that they are able to analyze the problem of environmental pollution in everyday life in detail. This research develops augmented reality-based online learning media using 4D design (Define, Design, Develop, Disseminate). The media that has been developed is tested for validation by four validators. In addition, an effectiveness test was also conducted through a field test. The effectiveness test was carried out using a quasi-experimental method with a pre-test and post-test one group design. Collecting data with a mental model description test that includes three levels of representation in chemistry, namely macroscopic, submicroscopic, and symbolic. Mental model tests were carried out before and after using AR media. Mental model data are analyzed using t-test. In addition, the data collection method also uses questionnaire to measure practicality of the product. The product is valid, practical, and effective with a validity score of 0.81, a practicality score of 84.39%. The product can develop students' mental models from initial type to scientific category. Based on the t test, AR media can significantly improve students' mental models with a significance value of 0.03.

Keywords: Augmented Reality · Mental model · Environmental pollution

1 Introduction

In studying chemistry, students are required to have the ability to relate three levels of chemical representation, namely macroscopic, submicroscopic, and symbolic [1]. This is because complete chemistry must be studied through these three levels of representation. The ability to represent the three levels of representation is termed a mental model [2]. A mental model is a representation of ideas in a person's mind that is used to explain

S. Hadisaputra et al. (Eds.): NiTRIC 2022, AHCPS 4, pp. 194–204, 2023.
https://doi.org/10.2991/978-94-6463-130-2_20

a phenomenon. Every chemical phenomenon that occurs in life can be explained using three levels of representation [3, 4].

Vosniadou & Brewer [5] stated that students' mental models can be categorized into three types, namely initial models, synthetic models, and scientific models. The initial model is a perception that is not in accordance with scientific knowledge. Synthetic models are perceptions that are partially incompatible with scientific knowledge. The scientific model is a perception that is in accordance with scientific knowledge.

Based on the results of previous research conducted by Supriadi, and co-workers [4, 6], most still need higher mental models (initials) in explaining phenomena at the submicroscopic level, and there are no students who have developed scientific mental models. They only explain the process of chemical reactions occurring at the macroscopic and symbolic levels. In addition, in the student's mental model, there are pre-concepts that can cause misconceptions or alternative conceptions [7]. This student's mental model is the cause of their low learning outcomes in each course.

Based on observations, the low mental model of students is due to learning in the Chemistry Education study program at the University of Mataram that that still needs to connect between macroscopic and submicroscopic representations. When studying the submicroscopic level, students do not relate it to the macroscopic level, and vice versa. When studying the macroscopic level (laboratory exercise), students do not relate it to the submicroscopic level. This causes students' mental models to be low and their understanding of the material incomplete. To overcome the low mental model of students, it is necessary to develop learning that connects the three levels of representation.

Three levels of representation can be visualized using modeling. According to Coll & Treagust [8] chemistry learning can take place effectively if using modeling. There are three important goals in chemical modeling, namely to create a simple form of an object or concept, to provide stimulation in the formation of concepts during learning, thus supporting the visualization of a phenomenon, and to provide an explanation of scientific phenomena. One of the lessons that can be developed to model chemistry is learning that uses augmented reality (AR) media. Behmke and co-workers stated that Augmented reality-assisted learning can improve students' mental models [9].

Ovens and co-workers explain that augmented reality technology is very good for modeling the submicroscopic level of a substance so that it can connect the three levels of representation [10]. This technology works based on image detection (image), and the image used is a marker [11, 12]. The image can be a macroscopic level of a substance, then the detection results will bring up the chemical formula and molecular shape of the compounds present in the substance [13]. AR technology can be used as distance learning if conditions do not allow for face-to-face learning [14].

The current pandemic condition causes learning to be carried out online to avoid transmission of the coronavirus, so AR media must be used online. AR media can be integrated with online learning developed by the ministry of education, namely SPADA (Online Learning System). The media is very suitable for online learning [15]. AR media which is integrated with the ministry of education SPADA can be used to teach students from other universities in order to support the implementation of the MBKM program. Learning media like this have yet to be widely developed in Indonesia.

One of the topics that require augmented reality media in online learning is the topic of environmental pollution. Students must know how a substance pollutes the environment so that they are able to find solutions to overcome them. Students must have a representation at the particulate level of substances that cause environmental pollution and relate it to the macroscopic level [16]. Based on observations, students do not yet have a submicroscopic picture of contaminants. Augmented reality media will make it easier for students to imagine the submicroscopic level of a pollutant.

Therefore, researchers are interested in developing online learning media based on augmented reality technology on the topic of environmental pollution and its effect on the mental model of students of the Chemistry Education Study Program, University of Mataram. This study aims to develop an online learning media based on augmented reality technology on the topic of environmental pollution that is valid, effective and practical.

2 Materials and Methods

This is a development research with a 4D development model (define, design, development and dissemination). This research will develop AR-based learning on the topic of environmental pollution. At the field trial stage, the quasi-experimental method will be used with the research design of one group pre-test post-test design. This study used 79 students who took environmental chemistry courses in 2021. Students were given pre-test and post-test. The pre-test and post-test used an instrument in the form of a description test that measured mental models and interview guidelines.

The development of AR-based learning media in this study refers to the 4D model. The definition stage is a stage that aims to determine and define the learning requirements. Several activities at the definition stage are initial analysis, student analysis, task analysis, concept analysis, and formulating learning objectives. The design stage is the stage that aims to prepare drafts of AR-based online learning media. The development stage is the stage that aims to produce AR-based online learning that has been revised based on input from experts in the field of chemistry education.

In the development stage, field trials were carried out on odd-semester students for the 2021/2022 academic year at the Chemistry Education Study Program, FKIP, University of Mataram. This test will see the effectiveness of AR-based learning through students' mental models.

The research instruments used to collect data were feasibility validation sheets by experts, practicality questionnaires, and mental model test instruments. The developed AR media was tested for feasibility by 3 experts, consisting of material experts, linguists, and presentation experts where the results of this assessment were used as the basis for determining the feasibility level of the learning developed. The practicality questionnaire was used to determine student responses to AR media on environmental pollution materials. The mental model test instrument was used to determine the effectiveness of AR-based learning on the topic of environmental pollution which contained two description questions.

The data from the assessment of the feasibility of augmented reality-based learning products were analyzed descriptively. Determination of the level of validity and product

Table 1. Decision category based on kappa moment

Interval	**Kriteria Validitas**
0.81–1.00	Very valid, can be used without revision
0.61–0.80	valid, can be used but need very small revision
0.41–0.60	quite valid, can be used but needs minor revision
0.21–0.40	less valid, it is not recommended to use because of major revisions
0.01–0.02	very less valid, should not be used
0.00	invalid, should not be used

Source: [17]

Table 2. Practicality category

No	Percentage range	Category
1	$80\% < x \leq 100\%$	Very practical
2	$60\% < x \leq 80\%$	Practical
3	$40\% < x \leq 60\%$	Quite practical
4	$20\% < x \leq 40\%$	Less practical
5	$0\% < x \leq 20\%$	Impractical

revision is determined using the Kappa Cohen formula, which is to determine the level of agreement from at least 2 validators [17]. The product validity criteria based on the kappa moment are given in Table 1.

Practicality and effectiveness tests were carried out at the field test stage. Practicality test was collected using a Likert scale questionnaire modified by Riduwan [18]. Practicality data obtained in the form of a percentage of the questionnaire score. The rubric of practicality criteria is given in Table 2. The effectiveness test was carried out using a quasi-experimental method with a pre-test and post-test one group design. Mental model test was given to 78 students before and after learning using augmented reality (AR) media. Students' mental models are determined using the rubric in Table 3. The data obtained were analyzed descriptively and used the t test.

3 Results and Discussion

In this study, a four-stage 4D development model was used. A 4D model was also used to describe the creation of the augmented reality app. To identify and specify requirements, the augmented reality app development process' needs analysis step was used. This stage includes the phases of the initial analysis, learner analysis, task analysis, concept analysis, and objective learning analysis. At this point, a discussion on the student learning report and the instructional material utilized thus far took place in an interview with two chemistry lecturers and a few students of University of Mataram.

Table 3. Student mental model rubric

Mental model category	Rubric
Initial model	All answers contain non-scientific descriptions and do not extend to the submicroscopic level
Synthetic model	Some of the answers are scientific and reach the submicroscopic level
Scientific model	Draw all components from scientific imaging to submicroscopic level

Source: [19]

Environmental chemistry has a connection to life. The environmental chemistry subject requires students to use real-life examples. The real-life examples are pollutants and natural resources. Pollutants and natural resources are two examples from the actual world. They must comprehend the three ways in which pollution and other environmental toxins are represented. To explain the three levels of representation is still unproductive and inefficient since learning media has never before used the term augmented reality. These factors make it vital to create augmented reality-based environmental chemistry learning materials in order to improve the learning experience [20]. The University of Mataram has the necessary infrastructure for using augmented reality applications. Additionally, every student owns at least one Android phone, which is particularly beneficial for using augmented reality apps during the learning process. The learner analysis follows, and it reveals that students were unable to make connections between the three levels of representation. The three levels of representation were not connected in the learning they received, which is why. The majority of student learning did not involve augmented reality media. To connect the three levels of representation—macroscopic, symbolic, and submicroscopic—they require augmented reality media [21]. Although there aren't many augmented reality learning resources, they will be crucial throughout the epidemic. The vast majority of students have never used augmented reality. Next, either individually or in groups, is the task analysis for the materials in the augmented reality app. The concept analysis that follows aims to identify the most crucial learning material and arrange it so that it can be included in an augmented reality app. The analysis of learning objectives, which is the stage's last step, aims to identify the competencies and learning accomplishment indicators that students must attain. The analysis of learning objectives, which has the aim of determining competency and indicators of learning achievement that students must achieve, is the last stage in this stage.

The design phase, which comes after the first, is where researchers choose an augmented reality multimedia design. Researchers mention the use of several programs, including Android, Unity, Blender, Vuforia, and Blender, in the creation of augmented reality apps. The researchers next determined the best media to use for disseminating the knowledge, which will be presented in the media as a multimodal learning experience, whether it be in the form of images, text, audio, or video. In order to manufacture the necessary components, researchers first take pictures of waste in a beaker to use as markers, then use the blender program to create molecular animations. Then, utilizing Unity software and the fuvoria website, the production step of augmented reality multimedia development was carried out. The app was created as a linear sequence of

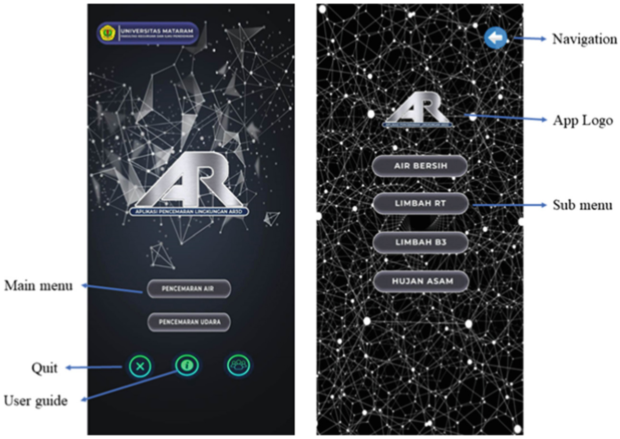

Fig. 1. Screenshot of the features of the app

Fig. 2. User guide

discrete learning modules that users could explore using navigation controls and included three-dimensional animations and written explanations. This strategy was chosen since it is simple to produce and apply. The researcher additionally creates a questionnaire instrument at this step to evaluate the expertise of the design/media expert and the material/content expert (Figs. 1, 2, and 3).

The development stage is the third stage. A media expert and a material expert evaluated the educational medium they had created. Product development trials utilize individual trials, small group trials, and outdoor testing. Researchers modify augmented reality multimedia to correspond to the set specifications using the findings of expert validation and development trials.

Fig. 3. Screenshot of Augmented Reality view with marker and its description

The stage that comes after is distribution. Because of time restrictions, researchers only complete the third stage, which is the creation of an augmented reality multimedia product.

Using the Kappa Cohen method, the app product's validation by four experts was examined. With a Kappa moment value of 0.81 and very valid criteria, it was determined that revision was not required.

Further, 79 fifth-semester students from the Chemistry Education Department at the University of Mataram participated in the Field Trial. The development of augmented reality media was used to instruct students. By measuring students' mental models both before and after using the products for learning and by having them complete questionnaires about practicality, field tests were done to ascertain the efficacy and viability of augmented reality application products. Students are instructed to sketch the molecular components of both liquid and gaseous pollution.

Effectiveness is seen from the changes in the types of students' mental models before and after learning using products that have been developed. There are three types of mental models, namely initial, synthetic, and scientific. Based on pre-test and post-test data, many students experienced an increase from initials to synthetic or scientific. In addition, there is also an increase from synthetic to scientific. Based on data analysis, it was found that there was an increase in the percentage of students who developed synthetic and scientific mental models, while the percentage of students who developed initial mental models decreased. The data on the change in the percentage of students' mental models can be seen in Fig. 4.

Based on Fig. 4, it can be seen that there was a decrease in the percentage of students who developed initial mental models from 71% to 35%, while the percentage of students who developed synthetic mental models increased from 29% to 43%. In addition, the percentage of students who developed a scientific mental model also increased, from none to 22%. In this study, there were students who developed a scientific mental model.

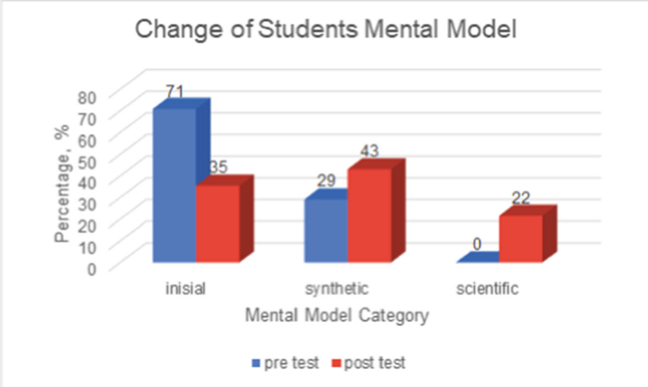

Fig. 4. Changes in student mental models

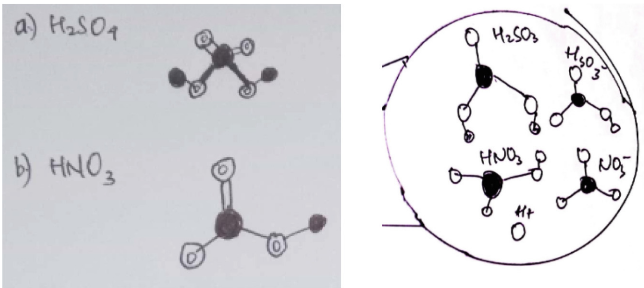

Fig. 5. An example of changing a student's mental model from initial to scientific

This is different from the results of previous studies, which stated that there were no students of Chemistry Education at the University of Mataram who had developed a scientific mental model even though it was in the final semester [4, 6]. The results of the t test showed that the developed AR media could improve students' mental models with a significance value of 0.03. It can be concluded that the use of augmented reality application products in online learning is effective in improving students' mental models. Changes in the description of the mental model of students can be seen in Fig. 5. Before learning, all students considered sulfuric acid (H_2SO_4) and nitric acid (HNO_3) not ionized in water. The development of AR technology makes it easier for students because they can find a different atmosphere when learning, such as visualization in 3D format [21]. The media can help students to see particulate (submicroscopic) level of substances [22].

Some students do not experience an increase in mental models because they have a difficulty in installing augmented reality applications. Due to the pandemic conditions, researchers were unable to assist in the installation process.

In addition to the effectiveness test, a practicality test was also carried out by filling out response questionnaires for students and lecturers. An augmented reality media of environmental pollution that is developed is included in the very practical category with an average percentage of the practicality of 84.39%.

4 Conclusion

We have already explained the process of developing an environmental pollution AR app product. The product is valid, effective, and practical with a validity score of 0.81, and a practicality score of 84.39%. The product can develop students' mental models from initial type to scientific category. Based on the t test, AR media can significantly improve students' mental models. For further research, the comparison of learning using AR with learning without AR will be investigated.

References

1. B. Davidowitz and G. Chittleborough, "Linking the Macroscopic and Sub-microscopic Levels: Diagrams," in *Multiple representations in chemical education*, Dordrecht: Springer, 2009, pp. 169–191. https://doi.org/10.1007/978-1-4020-8872-8_9.
2. Sunyono, L. Yuanita, and M. Ibrahim, "Supporting Students in Learning with Multiple Representation to Improve Student Mental Models on Atomic Structure Concepts," *Science Education International*, vol. 104, no. 2, pp. 104–125, 2015.
3. N. Jansoon, R. K. Coll, and E. Somsook, "Understanding Mental Models of Dilution International Journal of Environmental & Science Education Understanding Mental Models of Dilution in Thai Students," *International Journal of Environmental & Science Education* , vol. 4, no. 2, pp. 147–168, 2009, [Online]. Available: http://www.ijese.com/
4. Supriadi, S. Ibnu, and Yahmin, "Analisis Model Mental Mahasiswa Pendidikan Kimia dalam Memahami Berbagai Jenis Reaksi Kimia," *Jurnal Pijar Mipa*, vol. 13, no. 1, pp. 1–5, Apr. 2018, https://doi.org/10.29303/jpm.v13i1.433.
5. S. Vosniadou *et al.*, "Mental Models of the Earth: A Study of Conceptual Change in Childhood," *Cogn Psychol*, vol. 24, pp. 535–585, 1992.
6. S. Supriadi, W. Wildan, A. Hakim, L. R. T. Savalas, and M. Haris, "Model Mental dan Kemampuan Spasial Mahasiswa Tahun Pertama dan Ketiga Pendidikan Kimia di Universitas Mataram," *Jurnal Pijar Mipa*, vol. 16, no. 3, pp. 282–287, Jun. 2021, https://doi.org/10.29303/jpm.v16i3.1366.
7. N. E. Gayeta, "The Use Of Mental Models And Ill-Structured Problems In Determining Students" Alternative Conceptions In Stoichiometry," *International Journal of Advanced Research and Publications*, vol. 2, no. 12, pp. 46–50, 2018, [Online]. Available: www.ijarp.org
8. R. K. Coll and D. F. Treagust, "Investigation of secondary school, undergraduate, and graduate learners' mental models of ionic bonding," *J Res Sci Teach*, vol. 40, no. 5, pp. 464–486, 2003, https://doi.org/10.1002/tea.10085.
9. D. Behmke *et al.*, "Augmented Reality Chemistry: Transforming 2-D Molecular Representations into Interactive 3-D Structures," *Proceedings of the Interdisciplinary STEM Teaching and Learning Conference*, vol. 2, no. 1, Jan. 2018, https://doi.org/10.20429/stem.2018.020103.
10. M. Ovens, M. Ellyard, J. Hawkins, and D. Spagnoli, "Developing an Augmented Reality Application in an Undergraduate DNA Precipitation Experiment to Link Macroscopic and Submicroscopic Levels of Chemistry," *J Chem Educ*, vol. 97, no. 10, pp. 3882–3886, Oct. 2020, https://doi.org/10.1021/acs.jchemed.0c00481.

11. H. C. K. Lin, M. C. Chen, and C. K. Chang, "Assessing the effectiveness of learning solid geometry by using an augmented reality-assisted learning system," *Interactive Learning Environments*, vol. 23, no. 6, pp. 799–810, Nov. 2015, https://doi.org/10.1080/10494820.2013.817435.
12. S. Lorena, B. Ginting, Y. Rinaldy Ginting, and W. Aditama, "Augmented Reality Sebagai Media Pembelajaran Stimulasi Bayi Menggunakan Metode Marker Berbasis Android," *Jurnal Manajemen Informatika (JAMIKA)*, vol. 7, no. 1, pp. 1–14, 2017.
13. M. Al-Ghifari Rajmah, M. Adrian, and M. Barja Sanjaya, "Aplikasi Alchemist Menggunakan Augmented Reality Berbasis Android untuk Pembelajaran Kimia SMA," in *e-Proceeding of Applied Science*, 2017, pp. 1448–1460.
14. R. Pakpahan and Y. Fitriani, "Analisa Pemanfaatan Teknologi Informasi Dalam Pembelajaran Jarak Jauh di Tengah Pandemi Virus Corona Covid-19," *Journal of Information System, Applied, Management, Accounting and Research*, vol. 4, no. 2, pp. 30–36, 2020.
15. A. A. Sejzi, "Augmented Reality and Virtual Learning Environment," *J Appl Sci Res*, vol. 11, no. 8, pp. 1–5, 2015.
16. V. Talanquer, "Macro, submicro, and symbolic: The many faces of the chemistry 'triplet,'" *Int J Sci Educ*, vol. 33, no. 2, pp. 179–195, Jan. 2011, https://doi.org/10.1080/09500690903386435.
17. A. Asmiyunda, G. Guspatni, and F. Azra, "Pengembangan E-Modul Kesetimbangan Kimia Berbasis Pendekatan Saintifik untuk Kelas XI SMA/MA," *Jurnal Eksakta Pendidikan (JEP)*, vol. 2, no. 2, p. 155, Nov. 2018, https://doi.org/10.24036/jep/vol2-iss2/202.
18. Riduwan, *Belajar Mudah Penelitian.* Bandung: Alfabeta., 2012.
19. M. Altan Kurnaz and A. Yağmur Emen, "Mental Models of the High School Students Related To the Contraction of Matter," *ArticleInternational Journal of Educational Research and Technology*, vol. 4, no. 1, pp. 1–5, 2013.
20. A. Syawaludin, Gunarhadi, and P. Rintayati, "Development of augmented reality-based interactive multimedia to improve critical thinking skills in science learning," *International Journal of Instruction*, vol. 12, no. 4, pp. 331–344, Oct. 2019, https://doi.org/10.29333/iji.2019.12421a.
21. J. Latipah, S. N. Jamilah, S. T. Sari, and Almubarak, "Analysis of student's mental model through representation chemistry textbooks based on augmented reality," in *Journal of Physics: Conference Series*, Jan. 2021, vol. 1760, no. 1. https://doi.org/10.1088/1742-6596/1760/1/012050.
22. M. Munzil and P. R. A. Mentari, "Development of e-learning teaching material with augmented reality based on problem based learning for nature of chemistry and scientific methods topic as teaching material in Covid-19 pandemic," in *AIP Conference Proceedings*, Mar. 2021, vol. 2330. https://doi.org/10.1063/5.0043248.