Jurnal Pendidikan Terbuka dan Jarak Jauh
25(1), July 2024, pp.59-73
ISSN 2442-2266
DOI: 10.33830/ptjj.v25i1.7731.2024

An Ethnopedagogical Approach: The Design of AR-Based Mobile Learning of Molecular Geometry in Chemistry

Sukma Wahyu Wijayanti[1], Inas Sausan[2], Mario Aditya Prasetyo[3]

[1,2]Chemistry Education Study Program, FKIP, Universitas Terbuka, Tangerang Selatan, Indonesia
[3]Communication Science Study Program, FHISIP, Universitas Terbuka, Tangerang Selatan, Indonesia
Corresponding email: sukma.wahyu@ecampus.ut.ac.id
Article history:
Received: March 21st, 2024 Accepted: June 24th, 2024 Published: July 31st, 2024

Abstract *Learning media plays an important role in supporting the learning process of chemistry, especially in the topic of molecular geometry, to enable the delivery of material more concretely and to facilitate understanding of concepts by students. To address this, there is a necessity to develop a mobile learning application based on augmented reality specifically for molecular geometry material. The process of making this application refers to the Borg & Gall (2003) development model. This model consists of 10 phases, summarized into three main parts: design, development, and evaluation. This research specifically focuses on the initial stage, namely the design stage. The research method used is research and development (R&D). This implementation plan consists of two stages: data collection through needs analysis by distributing questionnaires to students and needs analysis from a professional perspective through interviews and literature research. The result of this research is an application design with content and functionality suitable for developing augmented reality-based mobile learning materials on molecular geometry in chemistry education*.

Keywords Ethnopedagogical, Design of Augmented Reality, Mobile Learning, Molecular Geometry

INTRODUCTION

Chemistry with general characteristics as an abstract subject requires adequate spatial and visualization skills for students to understand (Carlisle et al., 2015; Rahmawati et al., 2021), especially the molecular geometry material that discusses three dimensions. The difficulty faced by students when learning molecular geometry material is that students do not understand the meaning of the Lewis symbol, the effect of free electron pairs on molecular geometry, and various types of molecular geometry when given a case in placing the name and geometry of a molecule. (Nugraha et al., 2019). Many researchers have researched molecular geometry. The emergence of misconceptions in molecular geometry material is primarily due to students' difficulties visualizing three dimensions (Nugraha et al., 2019; Rohmah & Hidayah, 2022), so media or strategies are needed to minimize it.

Visualization at the submicroscopic level is an ability that is difficult to master, especially when learners are not equipped with sufficient knowledge of chemical content or lack spatial abilities. (Al-Balushi et al., 2017; Harle & Towns, 2011). Spatial ability is the ability to sketch/represent and translate 2D and 3D molecular models and their interactions. (Carlisle et al., 2015). Teachers need to provide practice or assistance to improve students' spatial abilities. It is intended that students no longer experience misconceptions or get low learning outcomes in molecular geometry material. Teachers can use *spatial language,* video games, and *augmented* reality media assistance in many ways, as discussed in previous research results. (Anam et al., 2022; Anwar et al., 2020; Sudirman & Alghadari, 2020).

Learning media is a solution often used to help students understand materials that are abstract, difficult, and require a high level of reasoning. (Nazar et al., 2020; Solikhin et al., 2019; Widarti et al., 2021). The characteristics of learning media in the form of visual and interactive are why this learning media is suitable for providing a detailed explanation of molecular geometry material. Learning media is a device that conveys learning content and facilitates the achievement of student learning goals. (Aksa, 2017; Ramadhani et al., 2016; Ramdani et al., 2020).. The more effective the learning media, the more influential the learning process so that the *outcome of* students in the form of learning outcomes is getting better.

In the current development, *augmented reality* (AR) is a field that is being actively researched, developed, and used as a *support for* learning media. (Aw et al., 2020; Cipresso et al., 2018; Macariu et al., 2020; Stefan & Moldoveanu, 2015; Krüger et al., 2019). These researchers state several characteristics of AR that can be potential in learning, such as contextual (AR users can experience the real and virtual world simultaneously), interactivity (the possibility to interact with AR through manipulation of natural objects and virtual properties), and spatiality (linking virtual objects to specific points in a more realistic three-dimensional space). From these characteristics, many researchers have developed this AR-based learning media. One of them is making AR-based *mobile learning* media because it is considered very likely to be used by students in their learning environment, both in and outside the classroom.

The ethnopedagogical approach is used as an approach that connects science with culture. This approach can help learners develop attitudes toward cultural values and the science obtained in the classroom. (Jannah, 2022; Rahmawati et al., 2020). Ethnopedagogy in science learning is related to classifying society, culture-related physical phenomena and cultural systems, and incorporating community values and knowledge (Khusainov et al., 2015). In addition, the ethnopedagogical approach is a system that explains nature for predictive purposes and practical applications (Wang, 2013). Only a few studies have linked the ethnopedagogical approach to developing learning media, especially in molecular geometry material. One of the advantages of ethnopedagogy is that it can help students to improve learning and preserve their identity (Rahmawati et al., 2020) and can be a consideration in applying it to the creation of AR-based *mobile learning* media.

The research question is how to design *mobile learning* with *augmented reality* technology on molecular geometry material with an ethnopedagogical approach. According to users and experts, this research aims to design *mobile learning* media as an open learning resource. As a novelty, *mobile learning* can support students' understanding of molecular geometry material through an ethnopedagogical approach so that it is expected to improve students' spatial abilities while being able to analyze their cultural products in everyday life. This research implies that students can have better spatial abilities, improve learning outcomes in molecular geometry material, and analyze cultural products in everyday life.

METHOD

The research method used in this study is development research or *Research and Development* (R&D). Development research is a research method used to produce specific products and test the effectiveness of these products. This research starts by analyzing the needs that need to be done to be able to produce specific products (Sugiyono, 2017). The product produced in this study is a learning resource in the form of *augmented reality-based mobile learning* that is expected to improve learners' understanding of the material in chemistry learning. Data was collected by distributing needs analysis questionnaires to students and teachers, interviews with experts in May-June 2023, and literature studies. The needs analysis data obtained is used for the next stage, development. The data analysis technique used in this research is quantitative descriptive analysis. The results of data analysis are used to identify things that must exist in learning molecular geometry material as a reference in designing *mobile learning* media. It is intended to find theoretical concepts to find the proper steps in developing these products (Sukmadinata, 2006).

RESULT & DISCUSSION

This research was focused on the design of making chemical learning media applications on one of the chemical bond materials, namely molecular geometry. The steps in making this *mobile learning* application are adapted from the Borg & Gall development model (2003), which consists of ten stages. The ten stages are summarized into three parts, namely design, development, and evaluation. This study lasted for two years. In 2023, the design and development part were conducted. In the following year, the evaluation part will be carried out. The following explains the research process that will be carried out in the first year, focusing on the design part. The design part consists of two stages, namely (1) data collection in the form of needs analysis and (2) *planning*. The following is an explanation of the application design activities.

A. Preliminary Analysis Stage

The preliminary analysis consists of research and data collection (*research and information*). The research and data collection stage was carried out by distributing a needs analysis questionnaire to teachers and students of the Chemistry Education Study Program, FKIP Open University. The questionnaire was filled in by 50 respondents in May-June 2023 through a *Google form* link. The questionnaire contains questions about the experience and opinions of respondents regarding the learning of molecular geometry that has been done. At this stage, experts were also interviewed to identify the features and content needed in the learning process of molecular geometry. Interviews were conducted with two chemistry teachers and two Chemistry Education Study Program students at FKIP (Faculty of Teacher Training and Education), Open University. The results of the questionnaire and interviews were used for the development stage. The following is the explanation.

Preliminary Analysis of Teachers and Students.

Based on the answers from the questionnaires that have been distributed, teachers and students have understood the molecular geometry material well, which is 96.7%. Therefore, it can be investigated the difficulties arising during learning the material from the perspective of teachers and students. The results show that 50% of respondents feel that the concept of molecular geometry material is classified as abstract. As many as 33.3% stated that they find it challenging to teach molecular geometry material because there is no learning media that is effective and adequate in understanding the material. It is due to the learning method that is usually used needs to be more varied. Based on the response, 76.7% of respondents stated that students understand molecular geometry material only through practice questions, 70% through discussion, 53.3% in lectures, and 46.7% through presentations. In addition, 60% of respondents stated that they had yet to use technology-based learning media in learning molecular geometry material.

Only a little exploration has been done using molecular geometry learning media. From the questionnaire, 83.3% of respondents still utilize blackboards and markers in explaining molecular geometry material, and 70% use simple PPT/ICT. On the other hand, 5% of respondents understood the importance of spatial knowledge in understanding molecular geometry material by using *molymod* media in the learning process. Therefore, as many as 76.7% of respondents agreed that making 3D modeling media from chemical bonds / molecular geometry is necessary to overcome the problem of students' difficulties in understanding molecular geometry material. As many as 60% of respondents from teachers and students also agreed to use learning videos as a solution to explaining molecular geometry material.

Regarding *mobile learning* knowledge, 63.3% of respondents already knew about *mobile learning*. However, from all responses, respondents stated that they rarely used *mobile learning* in the learning process or even not at all. In this modern era, learning using technological media significantly impacts learning (Sakat et al., 2012). Therefore, advanced technology can be utilized to develop more creative and innovative learning media. *Mobile learning* media is one of the options that can be used in the learning process. All respondents agree and are interested in *mobile learning being* used as a learning media for molecular geometry material with additional features of learning videos and practice questions. In addition, respondents also think that students' understanding can be improved by practicing 3D shapes to make them more attractive. Innovative *mobile learning* media makes learning more accessible, engaging, and practical (Huang et al., 2016).

Mobile learning is equipped with *Augmented Reality* technology *to practice 3D shapes.* 60% of respondents do not know *Augmented Reality* technology, and 83.3% of respondents have never used *Augmented Reality* technology in the learning process. From the advantages of *Augmented Reality*, 96.7% of respondents agreed that mobile learning based on *Augmented Reality* can facilitate understanding of the material and is suitable for studying molecular geometry. It is in line with the results of research by Iordache et al. (2012), which states that students understand more and learn chemistry quickly using augmented reality. Mustaqim (2016) also said that using *Augmented Reality* is very useful for interactive and authentic learning media directed by students.

Based on respondents' answers related to the ethnopedagogical approach, 60% of respondents need help understanding the approach, and 73.3% have never held a learning process with an ethnopedagogical approach. Implementing the current curriculum directs teachers to develop learning approaches to be more effective and preserve their culture. In the ethnopedagogy, research focused on Palembang Culture, with the results of 66.7% of respondents recognized Palembang cultural products such as *cuko pempek, pindang,* and *Palembang batik*. Learners' cultural background significantly affects the educational process if incorporated into the classroom learning process (Sumarni, 2016). It is because learners have spent their time in an environment influenced by community culture rather than formal education theory. More than 90% of respondents agreed if the material in molecular geometry mobile learning is integrated with Palembang culture so that learners can be interested in understanding learning contextually.

Expert Preliminary Analysis

Based on interviews conducted with experts, learning molecular geometry material is an essential basic concept and must be based on the previous material, namely Lewis structure.

> *"The success of* students *in chemical bonding material must be based on the initial understanding of* students *based on the previous material, namely the Lewis structure, if* students *need help in applying Lewis structure in describing valence electrons in an element. Then,* students *will need help in making chemical bonds. So far,* students *only practice chemical bonds using plasticine and toothpicks / molimods but are limited because it is difficult to describe free electron pairs, so visualized chemical bond models are limited* (Expert Interview, June 21, 2023)."

According to expert testimony, the things needed in learning molecular geometry are spatial abilities and concept understanding. In addition, learning molecular geometry is generally still focused on memorization skills and less training spatial abilities. Chemical material that is theoretical with memorization makes students less interested in learning it (Nuraeni, 2015).

Teachers must have creativity and innovation to create engaging and exciting student learning (Setyaningsih et al., 2015).

> *"Molecular geometry material is challenging for* students to *understand because the material requires spatial intelligence. In addition, they must have strong comprehension and analytical power because the material is introductory material that is very theoretical and conceptual, which has so far been taught by memorizing methods."*

Then there are some evaluations of the molecular geometry learning process that has been carried out. As stated by the expert:

> *"Needing an easy way to visualize complex and varied forms of chemical bonds due to the lack of easy and efficient tools."*

From the evaluation submitted, experts argue that using suitable media can make learning molecular geometry enjoyable.

> *"Learning by using media easily accessible to* students *with chemical bonding material with different atomic model colors can rotate according to the bond angle influenced by lone pair repulsion. Close to or even the same as the chemical bond with various colors and can be learned anywhere."*

From the interview, experts agree that the learning process on molecular geometry material uses *mobile learning* based on *Augmented Reality* because it can be used as alternative learning. In addition, *mobile learning* can add flexibility to teaching and learning activities. However, this *mobile learning* model still needs to be maximally utilized by parties or educational institutions, even though *it* can be used as an effective self-learning tool for students because they can freely access the available materials. (Alyahi et al., 2015).

> *"Agree, by using technology,* students *can learn more varied chemical bonds, a visual display that is fresher, more interesting, and the model is easily remembered by* students *so that* students *can be more enthusiastic in learning chemical bonds."*

Experts also agreed if ethnopedagogical approach is used in creating *mobile learning* content. Learners' cultural background significantly affects the educational process if incorporated into the classroom learning process (Sumarni et al., 2016). It is because learners have spent their time in an environment that is created/influenced by the culture of the community rather than formal education theory.

"It will be good and unique. Moreover, chemical bonding material cannot be seen with the naked eye. In addition, it can also add insight to students related to molecules in life so that learning becomes meaningful."

It is in line with the opinion of Saputra and Gunawan (2021), which states that developing engaging learning media will help students understand learning materials and absorb the information provided. Using learning media is essential so that the learning process becomes more effective. In addition to the use of active and exciting learning media, media that is easily accessible *online is* also needed in order to make it easier for students to understand the material provided. (Samoling et al., 2022). It cannot be separated from the characteristics of *online* learning, namely (1) interactive; (2) independent; (3) accessibility; and (4) enrichment. (Hamid et al., 2020).

In *mobile learning*, atomic modeling, practice questions, and materials are the features needed to learn molecular geometry.

"The selection of atomic models that are varied and different in color, the existence of lone pair repulsion, there are practice questions/quizzes, there is introductory material, short but concise material, and most importantly, 3D visualization of molecular shapes (Expert Interview, June 21, 2023)."

B. Planning Stage

Many chemical concepts are easier to understand if presented visually or in 3D. To be able to learn chemical bonding well, learners must be required to master spatial skills and have adequate spatial vision. Learners must understand bonding concepts, such as orbitals, electronegativity, electron repulsion, and polarity, that allow learners to predict and explain a substance's physical and chemical properties. Not all concepts can be explained simply by theory or by imagining the types of bonds formed.

Molecular geometry in chemical bonding material is included in the submicroscopic representation level. The concept of submicroscopic is natural but too small to be observed, so it requires the ability of imagination to understand it (Gilbert & Treagust, (2009). Hilton & Nichols (2011) found that understanding of chemical concepts will also increase if learners increase their representational competence. If learners find it easy to understand molecular geometry by using multiple representations, they can visualize concepts at the molecular level. Moreover, applying the ethnopedagogical approach can be contextualized learning so that students easily understand it. The product to be developed in this research and development will be *mobile learning that* can be accessed by all people as a medium of learning material molecular geometry based on *augmented reality* using an ethnopedagogy approach. The materials discussed in this developed product are bond formation, types of molecular shapes, polarity, and introduction to hybridization. The characteristics of molecular geometry material are abstract and a combination of conceptual understanding and application. Therefore, a learning process carried out by direct observation is needed to make learning more meaningful.

CONCLUSION

Based on the problems and the analysis of student and expert needs, it is known that *mobile learning* media is needed as an alternative learning resource for students that can be accessed via *smartphones* in learning molecular geometry material. The *mobile learning* media design is expected to improve students' spatial abilities because it is based on *augmented reality*. The advantage of this *augmented reality* method is an attractive visual display because it can display 3D objects that exist in the natural environment. This research produces a *mobile learning* application design that can be accessed using a *smartphone* with *an Android* operating system. The content in this media consists of AR simulations, materials, learning videos, quizzes, discussions, and info per the results of the analysis of student and expert needs. The results of the design stage are used for the next stage, which is application development.

DECLARATION OF CONFLICTING INTERESTS

The authors state that there is no conflict of interest in the publication of this article.

ACKNOWLEDGMENT

The researcher wishes to express gratitude to LPPM-UT for sponsoring this research in 2023. The researchers would also like to thank the experts, high school chemistry instructors, and students willing to serve as informants/resources for this study.

REFERENCES

Abi Hamid, M., Ramadhani, R., Masrul, M., Juliana, J., Safitri, M., Munsarif, M., ... & Simarmata, J. (2020). *Media pembelajaran [Learning media]*. Yayasan Kita Tulis.

Aksa, M. (2017). Classification and Characteristics of Historical Learning Media. *Advances in Social Science, Education and Humanities Research (ASSEHR)*, *158*(ICTTE), 37-43. https://doi.org/10.2991/ictte-17.2017.1

Al-Balushi, S. M., Al-Musawi, A. S., Ambusaidi, A. K., & Al-Hajri, F. H. (2017). The Effectiveness of Interacting with Scientific Animations in Chemistry Using Mobile Devices on Grade 12 Students' Spatial Ability and Scientific Reasoning Skills. *Journal of Science Education and Technology*, *26*(1), 70-81. https://doi.org/10.1007/s10956-016-9652-2

Alyahi, A. S., Nugroho, S., & Utomo, D. (2015). Aplikasi Mobile Learning Berbasis Web Service Menggunakan Sistem Operasi Android (Studi Kasus Fakultas Teknik Elektronika dan Komputer UKSW) [Web Service-Based Mobile Learning Application Using Android Operating System (Case Study of Faculty of Electronics and Computer Engineering UKSW)]. *Techné: Scientific Journal of Electrotechnics*, *14*(2), 137-146.

Anam, K., Wiradharma, G., & Prasetyo, M. A. (2022). Development of Mobile Learning Application Based on Augmented Reality Space Building Material. *Journal of Education and Instruction*, *5*(2), 678-693.

Anwar, M., Prabawa, W., & Sukamto, R. A. (2020). Augmented Reality-based Mobile Learning to Support Computer Assembly Learning. *Computer Teacher Journal*, *1*(1), 1-10. http://ejournal.upi.edu/index.php/JGrKom

Aw, J. K., Boellaard, K. C., Tan, T. K., Yap, J., Loh, Y. P., Colasson, B., Blanc, étienne, Lam, Y., & Fung, F. M. (2020). Interacting with Three-Dimensional Molecular Structures Using an Augmented Reality Mobile App. *Journal of Chemical Education*, *97*(10), 3877-3881. https://doi.org/10.1021/acs.jchemed.0c00387

Carlisle, D., Tyson, J., & Nieswandt, M. (2015). Fostering spatial skill acquisition by general chemistry students. *Chemistry Education Research and Practice*, *16*(3), 478-517. https://doi.org/10.1039/c4rp00228h

Cipresso, P., Giglioli, I. A. C., Raya, M. A., & Riva, G. (2018). The past, present, and future of virtual and augmented reality research: A network and cluster analysis of the literature. *Frontiers in Psychology*, *9*(NOV), 1-20. https://doi.org/10.3389/fpsyg.2018.02086

Gall, M. D., Gall, J. P., & Borg, W. R. (2003). *Educational Research: An Introduction* (7th ed.). Pearson.

Gilbert, J. K., & Treagust, D. F. (2009). Introduction: Macro, submicro and symbolic representations and the relationship between them: Key models in chemical education. In *Multiple representations in chemical education* (pp. 1-8). Springer.

Harle, M., & Towns, M. (2011). A review of spatial ability literature, its connection to chemistry, and implications for instruction. *Journal of Chemical Education*, *88*(3), 351-360. https://doi.org/10.1021/ed900003n

Hilton, A., & Nichols, K. (2011). Representational classroom practices that contribute to students' conceptual and representational understanding of chemical bonding. *International Journal of Science Education*, *33*(16), 2215-2246.

Huang, C. S. J. et al. (2016). Effects of Situated Mobile Learning Approach on Learning Motivation and Performance of EFL Students. *Journal of Educational Technology and Society*, *19*(1), 263-276.

Iordache, D., Pribeanu, C., and B. (2012). A Influence of specific AR capabilities on the learning effectiveness and efficiency. *Studies in Informatics and Control*, *20*(10), 1-8.

Jannah, M. (2022). Ethnopedagogical Approach in Multicultural Learning. *The 1st International Conference of Social Studies (ICSS) November 11th - 13th, 2022, 307-311*, 307-311.

Khusainov, Z. A., Gaisin, R. I., Biktimirov, N. M., Valiev, M. R., & Gilemhanov, I. R. (2015). Formation of ecological culture in the aspect of ethno pedagogy. *Mediterranean Journal of Social Sciences*, *6*(1S3), 126-130. https://doi.org/10.5901/mjss.2015.v6n1s3p126

Krüger, J. M., Buchholz, A., & Bodemer, D. (2019). Augmented reality in education: Three unique characteristics from a user's perspective. *ICCE 2019 - 27th International Conference on Computers in Education, Proceedings*, *1*(December), 412-422.

Macariu, C., Iftene, A., & Gîfu, D. (2020). Learn chemistry with augmented reality. *Procedia Computer Science*, *176*, 2133-2142. https://doi.org/10.1016/j.procs.2020.09.250

Mustaqim, I. (2016). Pemanfaatan Augmented Reality Sebagai Media Pembelajaran [Utilization of Augmented Reality as Learning Media]. *Journal of Technology and Vocational Education*, *13*(2), 174-179.

Nazar, M., Putri, R. I. C., & Puspita, K. (2020). Developing an android-based game for chemistry learners and its usability assessment. *International Journal of Interactive Mobile Technologies*, *14*(15), 111-124. https://doi.org/10.3991/IJIM.V14I15.14351

Nugraha, M., Supriatna, A., & Fatimah, S. S. (2019). Analysis of student difficulties based on respondents ability test on the topic of geometry molecules. *Journal of Physics: Conference Series*, *1280*(3). https://doi.org/10.1088/1742-6596/1280/3/032012

Nuraeni, Nurhayati, & H. (2015). Studi Komparasi Pembelajaran Menggunakan Kartu Destinasi dan Kotak Kartu Misterius Ditinjau dari Kemampuan Memori terhadap Prestasi Belajar Siswa pada Materi Pokok Koloid SMA Muhammadiyah 1 Karanganyar [Comparative Study of Learning Using Destination Cards and Mysterious Card Boxes in View of Memory Ability on Student Learning Achievement on the Subject Matter of Colloids at SMA Muhammadiyah 1 Karanganyar]. *Journal of Chemical Education*, *4*(2), 38-46.

Rahmawati, Y., Dianhar, H., & Arifin, F. (2021). Analyzing students' spatial abilities in chemistry learning using 3d virtual representation. *Education Sciences*, *11*(4). https://doi.org/10.3390/educsci11040185

Rahmawati, Y., Ridwan, A., Cahyana, U., & Wuryaningsih, T. (2020). The integration of ethnopedagogy in science learning to improve student engagement and cultural awareness. *Universal Journal of Educational Research*, *8*(2), 662-671. https://doi.org/10.13189/ujer.2020.080239

Ramadhani, D., Mulyani, B., & Utomo, S. (2016). Pengaruh Penggunaan Media Mobile Learning Berbasis Android Dan Lks Dalam Model Pembelajaran Student Team Achivement Division (Stad) Terhadap Prestasi Belajar Ditinjau Dari Kemampuan Memori Pada Materi Pokok Sistem Koloid Kelas Xi Sma Negeri 2 Purwokerto [The Effect of Using Android-Based Mobile Learning Media and Lks in the Student Team Achivement Division (Stad) Learning Model on Learning Achievement in View of Memory Ability on the Subject Matter of Colloidal Systems Class Xi Statema 2 Purwokerto]. *Journal of Chemical Education*, *5*(4), 16-25.

Ramdani, A., Jufri, A. W., & Jamaluddin, J. (2020). Pengembangan Media Pembelajaran Berbasis Android pada Masa Pandemi Covid-19 untuk Meningkatkan Literasi Sains Peserta Didik [Development of Android-Based Learning Media during the Covid-19 Pandemic to Improve Learners' Science Literacy]. *Journal of Education: Journal of Research Results and Literature Review in the Field of Education, Teaching and Learning*, *6*(3), 433-440. https://doi.org/10.33394/jk.v6i3.2924

Rohmah, N. U., & Hidayah, F. F. (2022). The Effectiveness of Using 3D Simulation Media in Online Learning of Molecular Geometry on Improving learning. *Journal of Chemistry Education Research*, *6*(1), 19-25.

Sakat, A. A. et al. (2012). Educational Technology Media Method in Teaching and Learning Progress. *American Journal of Applied Sciences*, *9*(6), 874-878.

Samoling, I. E., Ismanto, B., & Rina, L. (2022). Efektivitas Pembelajaran Daring Pada Masa Covid di SMAN 2 Salatiga [Effectiveness of Online Learning during the Covid Period at SMAN 2 Salatiga]. *Scholaria: Journal of Education and Culture*, *12*(1), 55-61.

Saputra, P. W., & Gunawan, I. G. D. (2021). Pemanfaatan Media Pembelajaran Digital Dalam Upaya Meningkatkan Efektivitas Pembelajaran Di Masa Covid-19 [Utilization of Digital Learning Media in an Effort to Improve Learning Effectiveness in the Covid-19 Period]. *In Proceedings of IAHN-TP Palangka Raya National Seminar*, *3*, 86-95.

Setyaningsih, A., Ariani, S.R.D., & Saputro, S. (2015). Studi Komparasi Pembelajaran Kooperatif Tipe Numbered Heads Together (NHT) dan Think Pair Share (TPS) terhadap Prestasi Belajar pada Materi Koloid Ditinjau dari Kemampuan Memori Siswa Kelas XI SMA Negeri 3 Sukoharjo Tahun Pelajaran 2013/2014 [Comparative Study of Cooperative Learning Type Numbered Heads Together (NHT) and Think Pair Share (TPS) on Learning Achievement on Colloid Material in View of Memory Ability of Class XI Students of SMA Negeri 3 Sukoharjo in the 2013/2014 Academic Year]. *Journal of Chemical Education*, *4*(1), 165-173.

Solikhin, F., Ikhsan, J., & Sugiyarto, K. H. (2019). A need analysis in developing virtual laboratory according to the chemistry teachers. *Journal of Physics: Conference Series*, *1156*(1), 1-6. https://doi.org/10.1088/1742-6596/1156/1/012020

Stefan, L., & Moldoveanu, F. (2015). Gamified 3D Virtual Learning Environment for Improved Students' Motivation and Learning Evaluation. A Case Study on "3DUPB" Campus. *The 11th International Scientific Conference ELearning and Software for Education*, *15*, 1-8. https://doi.org/10.13140/RG.2.1.1561.2002

Sudirman, S., & Alghadari, F. (2020). Bagaimana Mengembangkan Kemampuan Spasial dalam Pembelajaran Matematika di Sekolah?: Suatu Tinjauan Literatur [How to

Develop Spatial Ability in Mathematics Learning at School: A Literature Review]. *Journal of Instructional Mathematics*, *1*(2), 60-72. https://doi.org/10.37640/jim.v1i2.370

Sugiyono. (2017). *Metode Penelitian Pendidikan Pendekatan Kuantitatif, Kualitatif, dan R&D [Educational Research Methods Quantitative, Qualitative, and R&D Approaches]*. Alfabeta.

Sukmadinata, N. S. (2006). *Metode Penelitian Tindakan [Action Research Methods]*. Teenage Rosda Karya.

Sumarni, Woro, Sudarmin, Supartono, & W. (2016). Preliminary Analysis of Assessment Instrument Design to Reveal Science Generic Skill and Chemistry Literacy. *International Journal of Evaluation and Research in Education (IJERE)*, *5*(4), 331-340.

Wang, Y.-H. (2013). The Multicultural Science Literacy of Science Teachers in Taiwan. *International Journal of Asian Social Science*, *3*(9 SE-Articles), 2052-2059. https://archive.aessweb.com/index.php/5007/article/view/2562

Widarti, H. R., Rokhim, D. A., & Muchson, M. (2021). Developing Integrated Triplet Multi-Representation Virtual Laboratory in Analytic Chemical Materials. *International Journal OfInteractive Mobile Technologies*, *15*(8), 119-135. https://www.online-journals.org/index.php/i-jim/article/view/21573