International Journal of Applied Sciences and Smart Technologies

Volume 4, Issue 2, pages 159–172

p-ISSN 2655-8564, e-ISSN 2685-9432

Appropriate Technology-Based Project-Based Learning: 3D Printing Utilization for Learning Media Class

Monica Cahyaning Ratri[1*]

Chemistry Education Study Program, Faculty of Teacher Training and Education, Sanata Dharma University, Yogyakarta, Indonesia

[*]Corresponding Author: monicacahyaningr@usd.ac.id

(Received 01-10-2022; Revised 04-11-2022; Accepted 07-11-2022)

Abstract

Indonesia has more than ten thousand islands, making it an archipelago; therefore, the distribution of learning media and facilities over the country is difficult. This condition may affect the learning material delivery and the student's understanding. Thus, the *do-it-yourself* (DIY) learning media helps to overcome this condition. We investigated the usefulness of applying appropriate technology through the 3D printing technique to fabricate learning media inspired by local wisdom to meet the needs of learning media. The students were guided by a project-based learning (PjBL) method to find the problem, design their learning media, fabricate it using a 3D printer, and expected to be applied to deliver the teaching material in the class. This study aimed to observe the implementation of the designing process based on theory to reality. A qualitative method and questionnaire were used to measure student's responses. We found that PjBL learning based on a 3D printing project increases students' motivation through creativity and effectiveness in delivering the teaching materials.

International Journal of Applied Sciences and Smart Technologies
Volume 4, Issue 2, pages 159–172
p-ISSN 2655-8564, e-ISSN 2685-9432

Furthermore, 3D printed-based learning media can easily be fabricated, producing less waste.

Keywords: actuators and sensors, TCP socket, object detection

1 Introduction

Indonesia is a country with more than ten thousand islands, well known as one of the biggest archipelagos. Not only is the island huge, but the population of more than 275 million people also vary with various background and ethnic group, making it so diverse. Regional autonomy was chosen for the government system to maximize regional potential. Several problems arise due to those conditions in the education system and facilities.[1, 2] As the number of islands and the population wider, it will not be easy to even out the education facilities over the country.

Education is one of the crucial aspects of achieving a better society.[3] However, that stage remains challenging with the various ethnic backgrounds in Indonesia. The limited access to education facilities, the shortage of capable teachers, problems in the curriculum, and a high tuition fee to afford for most Indonesian are the challenging problems that need to be solved.[4-6] The solution should be found at the moment to solve that recent problem. Thus, education goals in Indonesia are soon to be achieved.

Chemistry is a mandatory subject that has to be taken during high school in Indonesia. Thus, the understanding of chemistry subject is one of the essential capabilities, even though chemistry has many abstract concepts.[7, 8] The structure of the compound is an example of the abstract phenomena in chemistry which has to be implemented in real life.[9] Therefore, the strategy to give a deep understanding of this matter is crucial. Moreover, chemistry subject also requires the student to recognize and capture the abstract molecule model of the compound. Hence, unlimited visualizing of abstract models is needed.[10] In chemistry, the boundary in the visualizing ability of students on abstract phenomena could be helped with the 3D imaging software using the computer or adjustable do-it-yourself (DIY) media.

Volume 4, Issue 2, pages 159–172
p-ISSN 2655-8564, e-ISSN 2685-9432

The likelihood of media visualizing the abstract concept in chemistry is preferable in delivering teaching material to achieve a deep understanding. Learning media plays a significant role in making abstract matter more real in teaching and learning, particularly. The effectiveness and efficiency of achieving learning objectives are increased with the involvement of learning media.[11] Chemistry is not a subject that is easy to be explained only verbally; however, the visuals also will help in the explanation of the new and novel ideas in chemistry. [12] Visual media help student to make the idea more accessible than the textbook material.[13] Based on those understanding, a recent learning media which can help students to increase the reality of the concept by involving the local wisdom to prevent the problem of the needed material and that easily made is necessary this recent time. Thus, the learning media not only help the student to understand more about the abstract concept, moreover help the teacher to visualize the theoretical ideas.

The problem in transportation to connect one island to another in Indonesia affects the mobility of school facilities such as learning media. Therefore, a new strategy, on-site fabrication learning media by utilizing local wisdom and appropriate technology, is required. Appropriate technology emerges as the new end-use product based on society's need with the integrated system.[14] The need for a product from the area is gathered into one data and based on that, a new design to fulfill the need is made. The fabrication of the designed product follows this, and the product is sent and able to be used by people, in this case, students.[15] 3D printing is the implication of appropriate technology able to meet the needs of learning media based on local wisdom. 3D printing is a process of fabrication of 3D design of the digital model and can be processed by various 3D printer type, layer by layer to make 3D object by joined and solidified with a computer.[16] The 3D printing technique allows the fabrication of complex designs easily with less waste.

In order to figure out the solution to the problem mentioned above, we designed a project-based learning (PjBL) activity in the learning media class. PjBL allows the student to look for the solution to the problem they face and design a plan to solve it.[17] Thus, the students could creatively create a new learning media based on local wisdom and the subject's needs using 3D printing technology. We investigate the

Volume 4, Issue 2, pages 159–172
p-ISSN 2655-8564, e-ISSN 2685-9432

effectiveness of the application of the 3D printing technique in the learning media class on the fabrication of learning media. The students' motivation and response were measured with the questionnaire through the google form. The students' response mentioned that learning media fabrication through PjBL with 3D printing was easy to design, fabricate, and maintain, and they thought that this learning media helps deliver teaching material in chemistry subject.

2 Research Methodology

The sample was one class of students in the learning media class, Chemistry Education study program, Sanata Dharma University, Yogyakarta. We used PjBL-based research with six steps approach.[18] We took 5 weeks to conduct this project. During the first meeting, students were introduced to the 3D printing technique, the basic information about a cartesian 3D printer used for this project, and the basic information about the 3D design software. Then, we applied the PjBL learning method in this class and gave the students project to be solved by utilizing the 3D printer to make DIY learning media. Students were allowed to identify the problem in learning material delivery that could be solved with the learning media.

The students were encouraged to find the problem in delivering the teaching material in high school chemistry subject as the first step. The second step was making a plan to solve the problem they found. The third step was scheduling the project, followed by students' weekly reports. Then, the student presented their results in the student exhibition, and the final step was reflections. The project started with the fabrication of the learning media based on students' findings. The first fabrication step was designing the learning media inspired by local wisdom into 3D digital design using Tinkercad. Then it was followed by a printing process using the 3D printer Ender 3 Pro with polylactic acid (PLA) filament as material. Weekly reports were mandatory to be handed to the teacher by students to control the students' progress, and discussion was opened during this time. After all, were done, the student had to present their result in an exhibition and explain the function and purposes of their learning media. In the end, we did the class reflection to reflect on our findings after we finished the project.

Volume 4, Issue 2, pages 159–172
p-ISSN 2655-8564, e-ISSN 2685-9432

The effectiveness of this project was measured by a questionnaire, including the student motivation, the easiness of the fabrication, and their response to the potential application. The questionnaire was given to the student through Google form after all the processes were completed; thus, the student's response was based on their experience.

3 Results and Discussion

Appropriate technology named with 3D printing technique was chosen for DIY learning media fabrication due to the simple instrument and its fabrication effectivity. Moreover, a 3D printer which is a relatively small instrument, only needs PLA filament as the material and is easy to travel to many places, even rural areas. Indonesia is an archipelago with a transportation problem to reach the rural area; however, it has prodigious local wisdom that inspires DIY learning media fabrication. In reference to those reasons, we conducted the study by applying the PjBL method to measure the effect of the application of appropriate technology on student motivation and the effectiveness of teaching delivery of chemistry subjects.

The research steps are presented in Figure 1, and the step started with a discussion on finding the problem. After students find the problem in delivering chemistry teaching material, then students make a plan to solve those problems. The solution involved the 3D printing in creating the new learning media. The scheduling project is the next step to continue the plans. After starting the fabrication step using 3D printing, students have to report their progress weekly to control the project's progress. The next step is after students complete their project; they present their results in the student exhibition (Supplementary Figure 1), followed by students' reflections. The reflection was then conducted to complete the step in this cycle and to, recall their experience during the project and share their motivation and the effectiveness of the 3D printing-based learning media.

In the last step, which was the reflection, the questionnaire was included on it. There were two parts of the question in the questionnaire about fabrication and the potential application of 3D printed learning media. The first part was about the students'

Volume 4, Issue 2, pages 159–172

p-ISSN 2655-8564, e-ISSN 2685-9432

responses on the fabrication, and the student's responses on the application were in the second part. The questions in every part are listed below:

1. Fabrication of learning media based on 3D printing is easy to design
2. Fabrication of learning media based on 3D printing trigger the creativity
3. Fabrication of learning media based on 3D printing is easy to fabricate
4. Fabrication of learning media based on 3D printing is easy to handle the waste
5. Fabrication of learning media based on 3D printing is easy to maintain
6. Application of learning media is maintainable (easy to maintain)
7. Application of learning media is usability (easy to operate and use)
8. Application of learning media is reusable
9. Application of learning media is effective and efficient
10. Application of learning media is the easy to delivered teaching material

Students' feedback was then collected and analyzed.

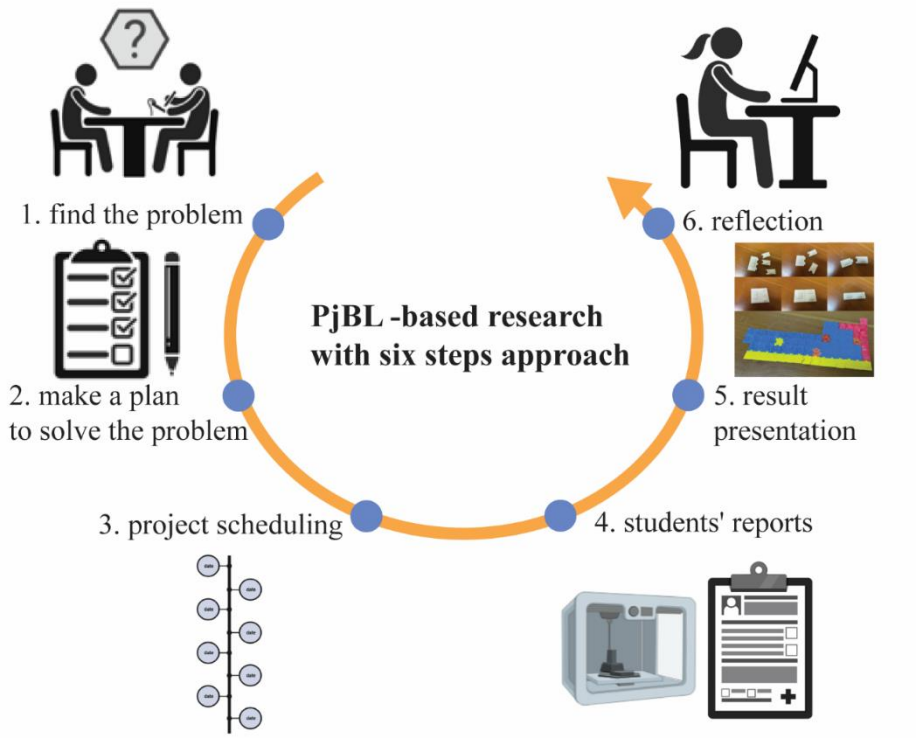

Figure 1. The experimental step on applying PjBL-based research with the six-step approach to measure the effectiveness of applying appropriate technology on the student's motivation and teaching material delivery.

International Journal of Applied Sciences and Smart Technologies

Volume 4, Issue 2, pages 159–172

p-ISSN 2655-8564, e-ISSN 2685-9432

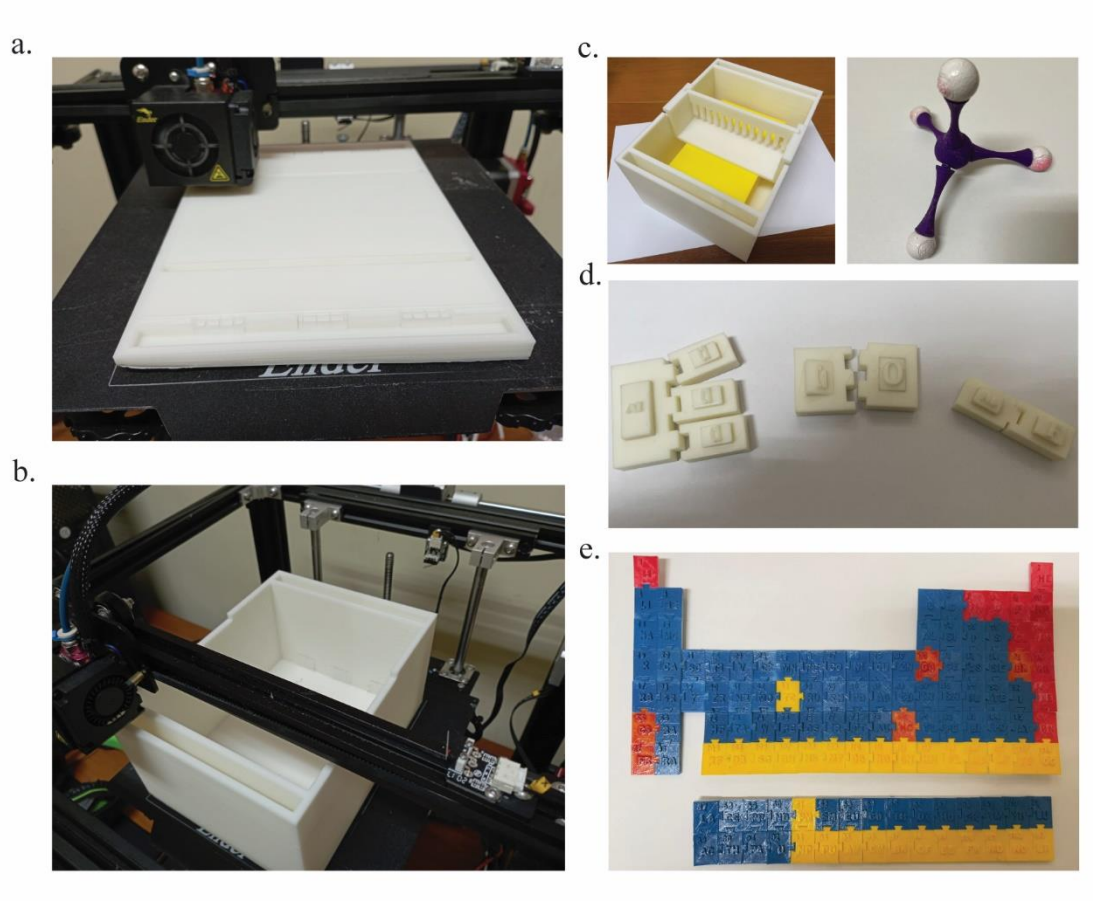

Figure 2. The printing process and 3D printed product for learning media. **a** and **b** are the printing process using the cartesian 3D printer for learning media products. **c.** 3D printed resemble electrophoresis instruments and molymod. **d**. 3D printed puzzle ionic bond and **e.** 3D printed embossed-periodic system of elements with specific colors based on their properties.

The PjBL cycle was conducted for 5 weeks. Students were given a chance to finish their projects and report their progress weekly on the learning management system (LMS) site. The report was needed to control the progress of students, and the teacher was able to discuss and give suggestions if needed. Figure 2 a and b show the fabrication process of learning media using a 3D printing technique that made a 3D learning media resemble electrophoresis instruments layer by layer using a cartesian 3D printer. The finished 3D printed learning media are shown in the Figure 2 c, d and f. In the Figure 2c, a resembling 3D electrophoresis instrument and molymod can be seen. A

Volume 4, Issue 2, pages 159–172
p-ISSN 2655-8564, e-ISSN 2685-9432

resembling 3D electrophoresis instrument is useful for explaining the electrophoresis process to students. Molymod also helps the teacher to explain the abstract concept of the molecular structure of the molecule to students. A 3D shape and visual presentation allow the students to construct an abstract concept to be more realistic; therefore, students' understanding can be enhanced.[19] The 3D-printed puzzle ionic bond is shown in Figure 2d**.** The puzzle is a traditional game in Indonesia; inspired by this local wisdom, the puzzle is aimed at giving the student another alternative in the learning process. The puzzle gaming method in delivering ionic bond topic potential to help students to heighten their motivation and learning result. [20] The 3D-printed embossed-periodic table of elements is shown the Figure 2e. The 3D embossed-periodic table of elements with specific colors based on their properties aimed to strengthen students' understanding of the difference of elements' properties visually.

The fabrication of learning media was governed by appropriate technology using the 3D printing technique. In the application of appropriate technology, we have to consider several things, such as the effectiveness of the technique in fulfilling the need, the easiness of fabrication, and also waste handling. Thus, the student's opinion of this technology should be known by surveying through the questionnaire. The student's response to this fabrication technique is presented in Figure 3. Based on the survey, students said the 3D printer was easy to maintain. Therefore, the 3D printer is usable in many places, even with minimal facilities, as long as electricity is provided. PLA filament was used as the material due to its affordability; PLA is a degradable biopolymer that is harmless to the environment.[21] Based on the survey, students said that the waste of this fabrication was easy to handle due to its biodegradability. 80% of students said the fabrication step was easy, and the rest said that it was difficult. This finding explains that student has a different level of motivation. Thus, the responses were different. All students agreed that this project motivated them by triggering their creativity. Students were obligated to solve the problems by creating learning media based on 3D printing inspired by local wisdom. Furthermore, a 3D electronic design was required for working with a 3D printer; therefore, students must learn how to make a 3D design based on their needs. Even though 10% of students agree that designing 3D objects was not easy, most students agree that the 3D design was easy to make.

International Journal of Applied Sciences and Smart Technologies

Volume 4, Issue 2, pages 159–172

p-ISSN 2655-8564, e-ISSN 2685-9432

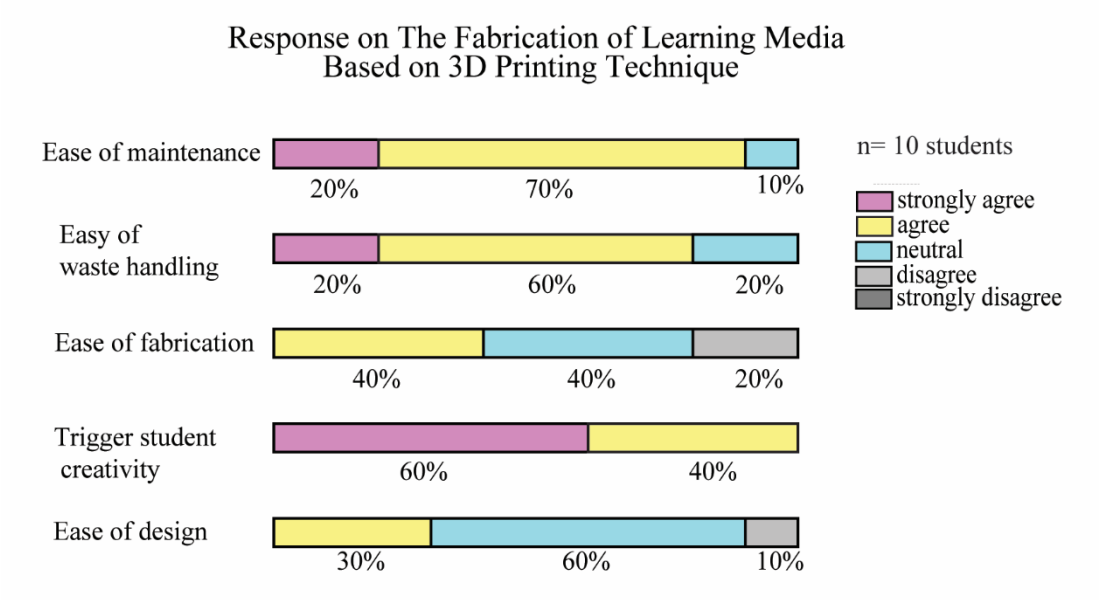

Figure 3. Summary of students' responses on the fabrication of learning media based on 3D printing technique. Students' responses were based on their motivation, which was expressed by their creativity and willingness to learn new techniques and designs.

A survey measured the effectiveness of the application of 3D printed learning media. The sample was students of a learning media class. Five indicators were used as representatives of the success of the learning media application. The indicators were: 1. learning media is maintainable (easy to maintain); 2. learning media usability (easy to operate and use); 3. learning media is reusable; 4. learning media is effective and efficient in delivering the teaching material; 5. learning media is easy to deliver teaching material. Student response on the application of learning media was great. The students were agree that 3D printed based learning media is easy to maintain during the delivering of the teaching material. The application of learning media was usefull for the students. That is importance because of the utilization of learning media able to maintain students interest, increase their analytical skill and enhance student attention.[19] Recently, due to the environmental problem and increased awareness of environmental sustainability, the fabricated learning media should be reusable. The survey shows that this 3D-printed learning media can potentially be used several times. Because chemistry is one of the subjects where most of the topics are abstract, the real

Volume 4, Issue 2, pages 159–172

p-ISSN 2655-8564, e-ISSN 2685-9432

learning media for chemistry subjects is preferred. The learning media ought to be visually accessible and present abstract concepts in reality.[12, 13] The students agreed that the learning media's application fulfilled that necessity. Based on the survey, students said that the learning media is effective and efficient in delivering the abstract concept in reality and easy to explain the abstract concept to be understandable. Therefore, this PjBL project's result shows us the potential of DIY learning media fabrication to fulfill the needs of local wisdom-inspired learning media.

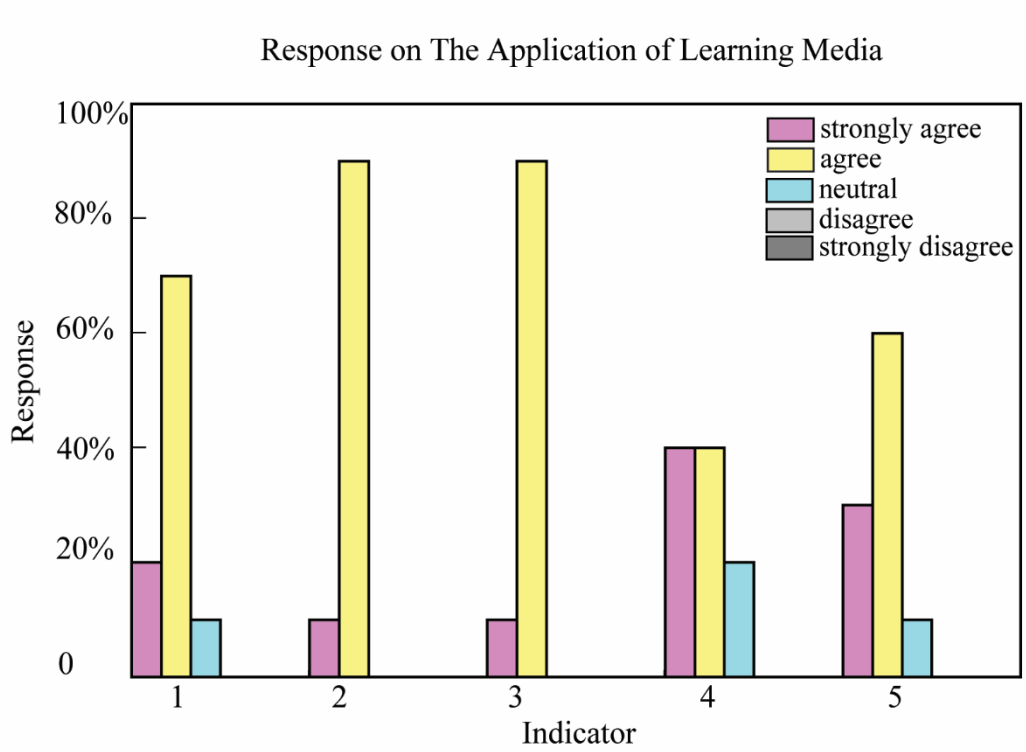

Figure 4. Summary of students' responses on the application of learning media based on 3D printing technique. Students' responses were based on the questionnaire, including the easiness of use, reusability, and the effectiveness of delivery of teaching material

4 Conclusion

The result of this study can be concluded that the PjBL-based 3D printed learning media fabrication enhanced students' motivation, easy to handle, operate and use. 3D printed learning media is also helpful and effective in delivering learning material. The material used for the filament is affordable and biodegradable, thus, harmless to the

environment. The easiness of travel the 3D printer make this 3D printing technique potentially used in many places, even in rural area.

Acknowledgment

The author wants to acknowledge the very generous contributions of Mr. Johnsen Harta and all the students in the learning media class, Chemistry Education Study Program, Sanata Dharma University. National research foundation of Korea for providing the 3D printer instrument for this research.

References

[1] L. Hakim, "Pemerataan akses pendidikan bagi rakyat sesuai dengan amanat Undang-Undang Nomor 20 Tahun 2003 tentang Sistem Pendidikan Nasional", *EduTech: Jurnal Ilmu Pendidikan Dan Ilmu Sosial,* **2**(1), 2016.

[2] R. Niswaty, M. Nasrullah, and H. Nasaruddin, "Pelayanan publik dasar Bidang Pendidikan tentang sarana dan prasana di Kecamatan Pulau Sembilan Kabupaten Sinjai", in *Seminar Nasional LP2M UNM*, **1**(1), 2019.

[3] C. Hopkins and R. McKeown, "Education for sustainable development: an international perspective", *Education and sustainability: Responding to the global challenge,* **13**, 13-24, 2002.

[4] A. B. Santosa, "Potret pendidikan di tahun pandemi: dampak COVID-19 terhadap disparitas pendidikan di Indonesia", *CSIS Commentaries,* 1-5, 2020.

[5] D. Hairi, "Respon Pemuda Perbatasan Dalam Menghadapi Keterbatasan Fasilitas Pendidikan Pada Pulau Combol Desa Selat Mie Kecamatan Moro Kabupaten Karimun", *Universitas Maritim Raja Ali Haji.*

[6] I. D. P. Subamia, "Analisis kebutuhan tata kelola tata laksana laboratorium IPA SMP di Kabupaten Buleleng", *JPI (Jurnal Pendidikan Indonesia),* **3**(2), 2015.

[7] A. O'Dwyer and P. E. Childs, "Who says organic chemistry is difficult? Exploring perspectives and perceptions", *Eurasia Journal of Mathematics, Science and Technology Education,* **13**(7), 3599-3620, 2017.

[8] G. Sirhan, "Learning difficulties in chemistry: An overview", 2007.

[9] H. K. Wu, J. S. Krajcik, and E. Soloway, "Promoting understanding of chemical representations: Students' use of a visualization tool in the classroom", *Journal of Research in Science Teaching: The Official Journal of the National Association for Research in Science Teaching,* **38**(7), 821-842, 2001.

[10] T. A. Holme, "Can We Envision a Role for Imagination in Chemistry Learning?", *Journal of Chemical Education,* **98**(12), 3615-3616, 2021.

[11] Y. D. Puspitarini and M. Hanif, "Using Learning Media to Increase Learning Motivation in Elementary School", *Anatolian Journal of Education,* **4**(2), 53-60, 2019.

[12] G. Salomon, "Media and symbol systems as related to cognition and learning", *Journal of educational psychology*, **71**(2), 131, 1979.

[13] P. S. Cowen, "Film and text: Order effects in recall and social inferences", *ECTJ*, **32**(3), 131-144, 1984.

[14] C. Brivio, "Off main grid PV systems: appropriate sizing methodologies in developing countries", 2014.

[15] M. Jiménez, L. Romero, I. A. Domínguez, M. d. M. Espinosa, and M. Domínguez, "Additive manufacturing technologies: an overview about 3D printing methods and future prospects", *Complexity*, 2019.

[16] M. C. Ratri, A. I. Brilian, A. Setiawati, H. T. Nguyen, V. Soum, and K. Shin, "Recent Advances in Regenerative Tissue Fabrication: Tools, Materials, and Microenvironment in Hierarchical Aspects", *Advanced NanoBiomed Research*, **1**(5), p. 2000088, 2021.

[17] J. Choi, J.-H. Lee, and B. Kim, "How does learner-centered education affect teacher self-efficacy? The case of project-based learning in Korea", *Teaching and Teacher Education,* **85**, 45-57, 2019.

[18] N. H. Fiktoyana, I., S. Arsa, P., Adiarta, A., "Penerapan Model Project Based Learning Untuk Meningkatkan Hasil Belajar Dasar Dan Pengukuran Listrik Siswa Kelas X-TIPTL 3, SMKN 3 Singaraja", *Jurnal Pendidikan Teknik Elektro Undiksha*, **7**(3), 90-101, 2018.

Volume 4, Issue 2, pages 159–172

p-ISSN 2655-8564, e-ISSN 2685-9432

[19] I. N. H. Fiktoyana, P. S. Arsa, and A. Adiarta, "Enhancing student interest in English Language via multimedia presentation", *International Journal of Applied Research,* **2**, 275-281, 2016.

[20] S. Y. Cheung and K. Y. Ng, "Application of the Educational Game to Enhance Student Learning, (in English)", *Frontiers in Education,* Original Research **6**, 31 March 2021.

[21] H. Tsuji and S. Miyauchi, "Enzymatic Hydrolysis of Poly(lactide)s: Effects of Molecular Weight, l-Lactide Content, and Enantiomeric and Diastereoisomeric Polymer Blending", *Biomacromolecules,* 2(2), 597-604, 2001.

International Journal of Applied Sciences and Smart Technologies

Volume 4, Issue 2, pages 159–172

p-ISSN 2655-8564, e-ISSN 2685-9432

This page intentionally left blank