Effects of Green Chemistry Based Interactive Multimedia on the Students' Learning Outcomes and Scientific Literacy

Saprizal Hadisaputra[1], Gunawan Gunawan[2],Muhammad Yustiqvar[3]*

[1]Chemistry Education Study Program, Universitas Mataram, 83125, Indonesia

[2]Physics Education Study Program, Universitas Mataram, 83125, Indonesia

[3]Master of Science Education, Universitas Mataram, 83125, Indonesia

Abstract.This study aimed to develop effective green chemistry-based interactive multimedia to improve students' mastery of concepts and scientific literacy. The research type is a research development using the 4D development model. The research was conducted at a high school in Lombok Indonesia which involved a control and experiment group. Pretest and posttest were given by researchers to test students' mastery of concepts and scientific literacy in chemistry. The effectiveness analysis was performed using the N-Gain test. The results showed that the mastery of concepts and scientific literacy of students in the experimental class was higher than in the control class. Testing the concept of mastery of the experimental class obtained an average score of 77% with high improvement criteria, whereas the control class obtained an average score of 68% with moderate improvement criteria. The scientific literacy of students in the experimental class received an average score of 85% with high improvement criteria, while the control class received a mean score of 65% with moderate improvement criteria. In conclusion, green chemistry-based multimedia increases the students' mastery of concepts and scientific literacy.

Keywords: multimedia, green chemistry, learning outcomes, scientific literacy.

Introduction

Chemistry learning outcomes in Indonesia are still in the low category. Chemistry is still the most difficult subject according to students. The study of Broman et al, (2011) showed students in 25 countries showed negative responses to chemistry. Another study showed that the average ability of Indonesian students in chemical content was ranked 45th out of 48 countries (Report of the national education minister, 2010). One contributing factor is students' low understanding of important chemical concepts that lead to student misconceptions (Ramandha, 2018; Andayani, 2019). The influence of misconceptions on chemical concepts has an impact on low student learning outcomes (Bowen and Bunce, 1997; Hwa and Kar-pudewan, 2017).

**Corresponding Author: G Gunawan, Email: gunawan@unram.ac.id*

Article History: Received: July 03, 2019, Accepted: Sep 27, 2019

In addition to the low chemistry learning outcomes followed by the low scientific literacy of students in Indonesia compared to other countries. In the 2012 PISA report (OECD, 2013) it was written that the average science score of Indonesian students was 382, where Indonesia ranked 64th out of 65 participating countries, or in other words the second lowest rank of all countries in the PISA study. The low scientific literacy skills of Indonesian students are influenced by the difficulty of students in linking the material learned with everyday life.

Another learning imperative is the importance of incorporating the concept of green chemistry in students' daily lives, especially in the classroom. Awareness of the importance of green chemistry must begin with students as early as possible. Green chemistry requires that product design and production processes must reduce the use of hazardous chemicals. The movement of green chemistry has begun in Indonesia, mainly by trying to integrate the concept of green chemistry into the learning curriculum.

Based on observations of schools in the city of Mataram it was found that one of the factors causing the low learning outcomes and scientific literacy is that the learning media used are still one-way so that the teacher's dominance in learning is very high. The use of this kind of media causes a boring learning environment. Studying in school is less interesting and less varied. Students feel bored and less interested in chemical materials so that the atmosphere of the class is passive. To overcome this problem, the teacher must make difficult material easy to learn.

In connection with these problems, it is necessary to renew in learning activities. The use of interactive multimedia based on green chemistry is a good alternative. Interactive multimedia can make it easier to display abstract concepts that are difficult to visualize or display directly in the laboratory (Husein et al., 2019; Wahyuni et al., 2019; Gunawan et al, 2019). The use of multimedia such as animation media can explain submicroscopic concepts that are difficult to explain further by students' textbooks (Mashami, 2018).

Advances in the application of technology and information in education have a direct influence on the development and guidance of the 21st. Implementation of good learning needs to use media as a tool in learning (Matic, 2013). The focus of this research is to develop interactive multimedia based on green chemistry used in chemistry learning. Evaluation on mastery of concepts and scientific literacy is done after learning using interactive multimedia.

Methods

This research is a development study using 4D design according to Thiagarajan (1974). The subjects in this study were students at the madrasyah aliyah Muslim school in Mataram. Sampling was determined using a cluster random sampling technique with an equivalent level of academic ability. Large-scale trials using the pretest-posttest control group design. The research instrument consisted of treatment and measurement instruments. The treatment instrument was a learning device used in the experimental and control class. Interactive chemistry based on green chemistry integrated in the contextual teaching and learning learning model applied to learning in the experimental class. The control class is taught with a contextual teaching and learning model without using interactive multimedia.

Measurement instruments consist of three types: 1. the concept mastery test instrument; 2. scientific literacy test instruments; and 3. questionnaire instruments for students' attitudes towards science learning. The instrument used to measure students' mastery of concepts and scientific literacy is a reasoned multiple choice test. Lee et al., (2011) states the superiority of this instrument compared to the usual multiple choice is that it can determine the ability of students in answering questions. Students not only choose the answer option, but there are consequences by giving an argument.

Science literacy tests are developed based on indicators of scientific literacy competencies. The indicators of scientific literacy competence in this study refer to the 2015 PISA scientific competency indicators. Scientific literacy indicators consist of: 1. explaining scientifically phenomena; 2. designing and evaluating scientific inquiry, 3. interpreting data and scientific evidence. Concept mastery indicators consist of C1 = remember; C2 = understand; C3 = apply; C4 = analyze; C5 = evaluate; C6 = create. The data analysis technique used is to use the N-Gain test which aims to determine the effectiveness of the applied multimedia.

Results

Pre-test data on the mastery of concepts and scientific literacy of students provides an overview of students' initial abilities before being given treatment by researchers. This pre-test is used to compare learning outcomes after students have been given both experimental and control classes. The average pre-test values of the experimental class and the control class is depicted in Table 1.

Table 1.Mean scores of students' pre-tests

Variables	Group	Value
Learning Outcomes	Experiment	37
	Control	39
Science Literacy	Experiment	28
	Control	29

*Corresponding Author: G Gunawan, Email: gunawan@unram.ac.id
Article History: Received: July 03, 2019, Accepted: Sep 27, 2019

Table 1 show that the pre-test scores on the understanding of concepts and science literacy of control class students were higher than those of the experimental class students. These results indicate that the initial ability of control class students is higher than the experimental class. Post-test data on the mastery of concepts and scientific literacy of students provide a picture of the student's final ability after being treated both for the experimental class and the control class. The treatment given is different between control and experimental classes. Experimental class learning uses interactive chemistry based on green chemistry with a contextual teaching and learning learning model, while the control class uses a contextual teaching and learning learning model without interactive multimedia. The average posttest score of the experimental class and the control class can be seen in Table 2.

Table 2. Post-test mean scores

Variables	Group	Value
Learning Out-come	Experiment	82
	Control	74
Scientific Lite-racy	Experiment	90
	Control	78

Table 2 shows that the post-test scores in the experimental class were higher than the control class. These results indicate that the final ability of the experimental class students is higher than the control class.

Pretest and posttest analysis of students' mastery of concepts and scientific literacy were further analyzed using the N-Gain formula. The N-gain value of concept mastery and science literacy of experimental and control class students is presented in Figure 1.

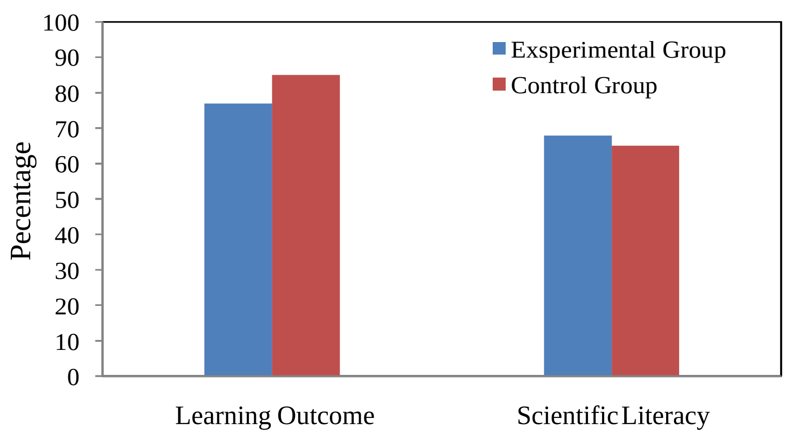

Figure 1. N-Gain values of experimental and control classes

Figure 1 shows the experimental class received grades increase with higher criteria, while the control class scored the average increase in the middle criteria. These results indicate that an increase in the average value of the mastery of concepts and scientific literacy learner's experimental class is higher than the control class learners.

N-Gain test results of students' mastery of concept data in the experimental class andthe control class of each indicator are presented in Figure 2. Furthermore, scientific literacy of students is presented in Figure 3.

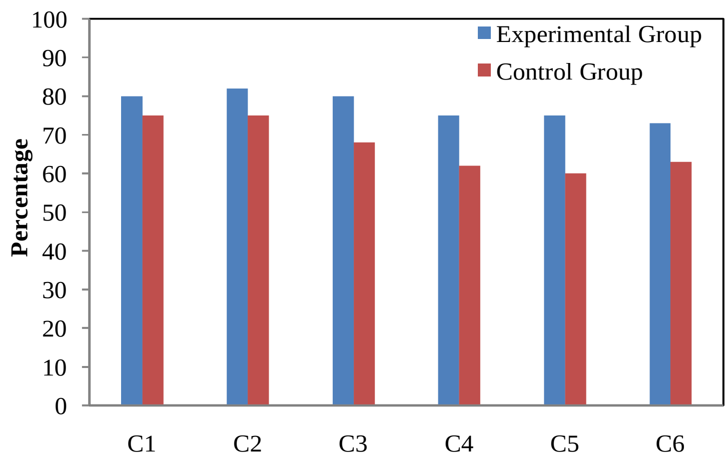

Figure 2. Science literacy test results indicators. C1= remember; C2= understand; C3= apply; C4 = analyze; C5= evaluate; C6= create.

Figure 2 shows that the average value of students on C3 indicator obtained the highest value compared to indicators C1, C2, C4, C5, and C6. These results indicate that the ability to translate learning material in the real world is higher than other students' ability indicators.

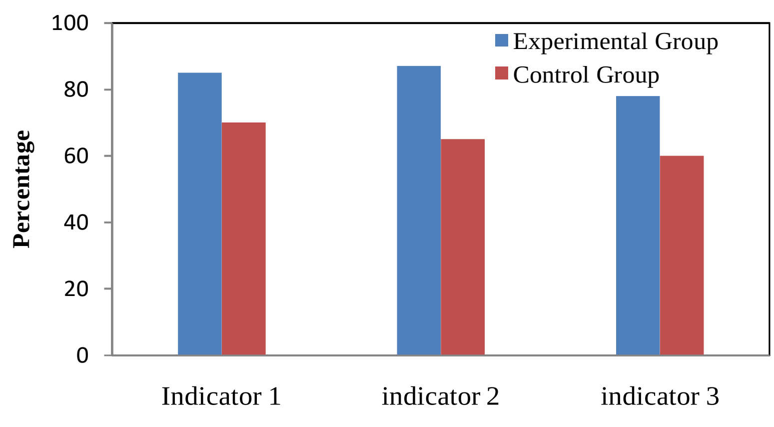

Figure 3. Test results for each indicator of scientific literacy. Indicator 1. explaining scientifically phenomena; indicator 2. designing and evaluating scientific inquiry; indicator 3. interpreting data and scientific evidence

Corresponding Author: G Gunawan, Email: gunawan@unram.ac.id
Article History: Received: July 03, 2019, Accepted: Sep 27, 2019

Figure 3 shows that the average value of students on indicators 1 and 2 has an increase in value with high criteria, whereas the average value of students on indicator 3 obtains an increase in value with medium criteria. The increase in the average value of scientific literacy of each indicator of students in indicators 1 and 2 is higher than indicator 3.

Discussions

The results showed that the average value of mastery of concepts and scientific literacy of the experimental class was higher than the control class. The advantage of the experimental class is in the learning process using interactive multimedia based on green chemistry that presents abstract, microscopic, symbolic concepts with a contextual teaching and learning model. The control class is taught without using interactive multimedia. It can be concluded that the influence of the use of interactive multimedia based on green chemistry on the mastery of concepts and scientific literacy of students.

Furthermore Lee and Osman (2012) stated that the experimental class students who were taught with interactive multimedia had a higher understanding of concepts than the control class. In addition, Pekdağ (2010) states that utilizing multimedia in the learning process increases students' understanding abilities. Theoretical reasons that can be used as a basis to justify that the acquisition of the experimental class is better than the control class. Interactive multimedia has the advantage of adding variations in the learning process and increasing student motivation in learning (Zoran, 2018). According to Wiana (2018) the use of interactive multimedia helps to improve student understanding.Carey (2013) states that there are differences in student cognitive learning outcomes in inquiry learning using multimedia compared to inquiry learning that does not use multimedia. Yulianci (2018) states that there is an influence of the use of interactive multimedia on student cognitive learning outcomes. In addition, Ristanto (2017) states that there are differences in scientific literacy between learning using the guided incur model with the media compared to conventional learning. The experimental class has higher scientific literacy compared to the control class.

The application of interactive multimedia also creates a sense of joy in students because it is able to arouse student curiosity and motivate students (Wiana, 2018: Yustiqvar, 2019). In addition to interactive chemistry based on green chemistry, the contextual teaching and learning model also plays a role in efforts to present problems that are close to students' daily lives (Suryawati, 2018). This is proven by the high enthusiasm of students in the experimental class when implementing learning. At the beginning of learning, it appears that there are still many students who have difficulty in operating interactive multimedia, but once the educator conveys instructions for use, that's when students begin to be active.

Student enthusiasm has increased since the implementation of learning using interactive chemistry based on green chemistry. Every student becomes active and enthusiastic about learning. Learning with interactive chemistry based on green chemistry starts at the first meeting in the class, but students still find it difficult. This is because learning is still new for students. The second and third meeting of students began to understand how to use interactive multimedia based on green chemistry. Educators have said that the next meeting will be held the same learning with the first meeting again with different sub material. After the third meeting the students were very active in participating in the learning, in addition to being able to operate interactive multimedia, students also answered every problem presented in the student worksheet.

Student enthusiasm is also influenced by the creativity of educators. The teacher conveys that students who can solve questions on student worksheets and interactive multimedia are given awards. This gives additional motivation for students in mastering concepts. A successful learning process impacts students' mastery of concepts and scientific literacy. The value of mastery of concepts and scientific literacy of these students can be seen after students work on the posttest. The question is close to what they have learned using interactive multimedia and student worksheets. Students have no trouble answering posttests. Students do not need to memorize learning material with all kinds of difficulties because it has been facilitated by multimedia applied in class. All material has been presented on learning using interactive multimedia while working on students' worksheets.

Microscopic and abstract concepts that are difficult to explain in more detail in other student handbooks can be explained through interactive multimedia based on green chemistry. Research by Adawiyah et al. (2019) and Gunawan et al., (2018) have stated that the application of computer-based media is able to assist teachers in conveying abstract concepts into simple visualizations that can be easily observed by students. Shahroni (2019) states that the complexity of the subject matter can be simplified with the help of the media. The media bridges what teachers are less able to say through certain words or sentences. Different conditions occur in the control class. The application of the contextual learning model is done without interactive chemistry based on green chemistry. In the control class, learning takes place using the contextual learning model by using student worksheets that were developed without special treatment as in the experimental class. This is the reason why students' grades in this class have a lower increase than the experimental class.

The increase in students' scientific literacy is also reviewed based on each indicator of scientific literacy. Data analysis shows that the highest scientific literacy value of students is achieved on indicators explaining the phenomenon scientifically. The ability of students to explain phenomena scientifically is clearly seen. This is caused by the application of interactive multimedia based on green chemistry which is integrated with the contextual teaching and learning model in the learning process.

*Corresponding Author: G Gunawan, Email: gunawan@unram.ac.id
Article History: Received: July 03, 2019, Accepted: Sep 27, 2019

Contextual teaching and learning relates to everyday life. Learning chemistry is closely related to daily life so that the ability of students in explaining the phenomenon is very good. Indicators of ability to interpret data and scientific facts are lower than indicators of ability to evaluate and design scientific investigations. Indicators that explain phenomena scientifically with good criteria are shown by the ability of students to apply science knowledge in solving scientific literacy problems. Learning that gives students the opportunity to develop ideas based on scientific methods will greatly help students improve their learning outcomes (Gunawan et al., 2019).

The concept knowledge possessed by students influences their ability to explain phenomena scientifically. This is in line with research conducted by Mawardini (2015) which states that indicators that explain phenomena scientifically obtain a score of 77% higher than other indicators. This is related to the learning process carried out in the classroom, students have been trained to explain phenomena scientifically by giving examples of phenomena that are around them.

The indicator of scientific literacy in the form of the ability to use scientific evidence is illustrated by the ability of students to interpret scientific evidence and draw conclusions by interpreting the data contained in several tables and pictures on the instrument of scientific literacy test questions used in this study. In addition, the ability of students is still lacking in interpreting scientific facts. The ability to interpret data and scientific evidence shown to obtain an increase score with moderate criteria. Students are not accustomed to interpreting data, so activities that maximize their ability to interpret data need to be trained in the learning process. Asrizal(2018) states that the indicators of scientific literacy in interpreting data get the lowest score compared to their indicators.

Students with the ability to recognize the key issues of the phenomena contained in the literacy test instruments are scientifically investigated. The ability of students to identify scientific issues is closely related to aspects of scientific knowledge. Analytical questions on literacy questions link students' cognitive aspects with the phenomena commonly encountered in their lives. Based on cognitive learning theory, students use their initial knowledge to process new information by linking the new information with the initial knowledge they have. Learners with the ability to know the issues and the key traits of phenomena contained in the instrument of literacy problems are investigated scientifically. The ability of learners in identifying scientific issues is of course closely related to aspects of scientific knowledge related to what they understand the concept of acids and bases. Question on item analysis linking cognitive literacy learners the phenomenon commonly encountered in life. Based on cognitive learning theory, learners use the knowledge initially to process the new information by connecting new information with prior knowledge they had. The scientific literacy aspects of the evaluation indicators and designing scientific inquiry have high improvement criteria. This criterion is influenced by the ability of students in terms of evaluating matters related to green chemistry.

Conclusions

The results of the research on the effectiveness of interactive chemistry based on green chemistry provide the following conclusions: (1) interactive multimedia based on green chemistry is effective for increasing mastery of concepts and scientific literacy of students. (2) Scientific literacy indicators explaining phenomena scientifically have increased higher than indicators of designing and evaluating scientific inquiry and indicators of interpreting scientific data and evidence. (3) The C3 indicator applies higher than the remember C1, understand C2, analyze C4, evaluate C5, and create C6 indicators.

Acknowledgments

The research is financially supported by Ristekdikti Grant number 1870/UN18. LI /PP/2019 and their support is gratefully acknowledge.

References

[1] Adawiyah, R., Harjono, A., Gunawan, G., & Hermansyah, H. (2019). Interactive E-book of Physic to Increase Student's Creative Thinking Skills on Rational Dynamics Concept. *Journal of Physics: Conference Series. 1153*(1)012117

[2] Andayani, Y., Hadisaputra, S., & Hasnawati ,H. (2018). Analysis of the Level of Conceptual Understanding. *Journal of Physics: Conference Series*. *1095*(1)012045.

[3] Asrizal, A., Amran, A., Ananda, A., Festiyed, F., & Sumarmin, R. (2018). The Development of Integrated Science Instructional Materials to Improve Students' Digital Literacy in Scientific Approach. *Jurnal Pendidikan IPA Indonesia*, *7*(4), 442-450.

[4] Bowen, CW., & Bunce, DM. (1997). Testing for conceptual understanding in general chemistry. *The Chemical Educator*, *2*(2)

[5] Shivshankar r. Mane (2019) advances of hydrazone linker in polymeric drug delivery. Journal of Critical Reviews, 6 (2), 1-4. doi:10.22159/jcr.2019v6i2.31833

[6] Pankaj Haribhau Chaudhary, Mukund Ganeshrao Tawar. "Pharmacognostic and Phytopharmacological Overview on Bombax ceiba." Systematic Reviews in Pharmacy 10.1 (2019), 20-25. Print. doi:10.5530/srp.2019.1.4

[7] Malmathanraj, R., and M. Arun. "A distributed e-healthcare system for patient monitoring and diagnosis." In 2012 IEEE International Conference on Advanced Communication Control and Computing Technologies (ICACCCT), pp. 71-77. IEEE, 2012. Gunawan, G., Suranti, N. M. Y., Nisrina, N., Herayanti, L., & Rahmatiah, R. (2018). The Effect of Virtual Laband Gender Toward

**Corresponding Author: G Gunawan, Email: gunawan@unram.ac.id*
Article History: Received: July 03, 2019, Accepted: Sep 27, 2019

Student’s Creativity of Physic in Senior High School. Journal of Physics: Conference Series. 1108(1)012043.

[8] Gunawan, Harjono, A., Susilawati, & Dewi, S. M. (2019). Generative Learning Models Assisted by Virtual Laboratories to Improve Students’ Creativity in Physics. Jour of Adv Research in Dynamical & Control Systems, 11, 313-320.

[9] Husein, S., Harjono, A., & Wahyuni, S. (2019). Problem-Based Learning with Interactive Multimedia to Improve Students’ Understanding of Thermodynamic Concepts. In *Journal of Physics: Conference Series*, 1233(1), p.012028.

[10] Hwa, T. H., & Karpudewan, M. (2017). Green Chemistry-Based Dual-Situated Learning Model: An Approach that Reduces Students’ Misconceptions on Acids and Bases. In *Overcoming Students' Misconceptions in Science* (pp. 133-155). Springer, Singapore.

[11] Irina, A., Irina, B., Anatasia, G., & Elena, D. (2019). Active Learning Technologies In Distance Education Of Gifted Students. *International Journal of cognitive Reserach in Science, Engineering and Education (IJCRSEE),7*(1), 85-94

[12] Lee, H.S., Liu, O.L., & Liin, M.C. (2011). An Investigation of Explanation Multiple-Choice Items in Science Assessment. *Educational Assessment*, *16*(3), 164-184

[13] Lee, T. T., & Osman, K. (2012). Interactive Multimedia Module in the Learning of Electrochemistry: Effects on Students’ Understanding and Motivation. *Procedia-Social and Behavioral Sciences*, 46, 1323-1327.

[14] Mashami, R. A., & Gunawan, G. (2018). In Influence of Sub-Microscopis Media Animation on Students’ Critical Tinkng Skills Based on Gender. *Journal of Physics: Conference Series. 1108*(1)012106.

[15] Matic, V. (2013). Teaching and Learning of Ecology for The Students of Vocational Secondary Schools in Multimedia Environment. *International Journal of cognitive Reserach in Science, Engineering and Education (IJCRSEE),1*(2), 21-32

[16] OECD. (2013). *Education at a Glance 2013 : OECD Indicators, OECD Publishing.*

[17] Pekdağ, B. (2010). Alternative methods in learning chemistry: Learning with animation, simulation, video and multimedia. *Journal of Turkish Science Education*, *7*(2), 111-118.

[18] PISA. (2015). *Draft Science Framework PISA 2015*

[19] Ramandha, M. E. P., Andayani, Y.,&Hadisaputra, S. (2018). An analysis of critical thinking skills among students studying chemistry using guided inquiry models. *AIP Conference Proceedings. 2021*(1)080007.

[20] Ristanto, H. R., Zubaidah, S., Amin, M., & Rochman F. (2017). Scientific Literacy of Students Learned Through Guided. *International Journal of Research & Review, 4*(5), 23-30

[21] Suryawati, E., & Osman, K. (2018). Contextual learning: innovative approach towards the development of students' scientific attitude and natural science performance. *Eurasia Journal of Mathematics, Science and Technology Education*, *14*(1), 61-76.

[22] Thiagarajan, Semmel,& Sivasailam (1974)*Instructional Development for Training Teachers of Exceptional Children*. Washington DC: National Center for Improvement Educational System.

[23] Wahyuni, S., Kosim, Gunawan, & Husein, S. (2019). Physics Learning Devices based on Guided Inquiry with Experiment to Improve Students' Creativity. In *Journal of Physics: Conference Series*, 1233(1), p.012034

[24] Wiana, W., Barliana, M.S., & Riyanto, A. A. (2018) The Effectiveness of Using Interactive Multimedia Based on Motion Graphic in Concept Mastering Enhancement and Fashion Designing Skill in Digital Format. *International Journal of Emerging Technologies in Learning, 13*(2): 1-20

[25] Yulianci, S., Gunawan, G., & Doyan, A. (2018). The Effect of Guided Inquiry Model with Interactive Multimedia Towards Student's Generic Science Skill Based on Learning Styles. In*2nd Asian EducationSymposium. 1*(1) 193-198. ScitePress.

[26] Yustiqvar, M., Gunawan, G., Hadisaputra, S., Bon, A. T. (2019). Interactive Multimedia Product Basedon Green Chemistry in the Acid-Base Concept of Chemistry Learning Process. *Proceedings of the International Conference on Industrial Engineering and Operations Management, 2082-2086.*

[27] Zoran, S., Jelena, M., & Jelena, O. (2018). Cognitive Theories and Paradigmatic Reserach Posts in the Function of Multimedia Teaching and Learning. *International Journal of cognitive Reserach in Science, Engineering and Ed.*

**Corresponding Author: G Gunawan, Email: gunawan@unram.ac.id*
Article History: Received: July 03, 2019, Accepted: Sep 27, 2019