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STEM VIRTUAL LAB : AN ALTERNATIVE PRACTICAL MEDIA TO ENHANCE STUDENT'S SCIENTIFIC LITERACY

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ABSTRACT

This research aimed to develop a STEM-based virtual lab as an alternative media in improving scientific literacy of junior high school students on the theme of water pollution. Development is done by using 4D methods: Define, Design, Develop, and Disseminate. After the implementation was done, it's effectiveness in increasing scientific literacy was examined using one group pretest-posttest design. At the define stage problems from PISA 2012, KDs, and STEM characteristics were analyzed. Design of flowcharts, storyboards, and user interface were done on design phase. Phases of develop includes the creation of virtual labs and validation by media expert and a science teacher. Phases of disseminate this research is to implement limited to two classes of junior high school students. The results from media expert validation and science teachers validates that STEM-based virtual labs that have been developed shows very decent used in the feasibility study by percentage according to media expert at 86.24% and 82.71% according to science teacher. The results show that the implementation of the STEM-based virtual lab that has been developed can improve scientific literacy of students with a large increase (N-gain) in the class 7B of 0.46 which falls in to medium category and class 7D of 0.29 with medium category.

Keywords: virtual lab, STEM, Scientific Literacy, media learning science, Development

INTRODUCTION

Science, technology, engineering, and mathematics (STEM) is a thematic approach in the development of science education. STEM education is constructed as a new whole and holistic body of knowledge based on constituting discpilines (Sanders, 2009). STEM is an important component in 21st century education. It is of an utmost importance to promote STEM in today's education system (Becker & Park, 2011). Integration of several disciplines into one comprehensive subject is hoped to help build not only a knowledgeable, but also competent student who are able to implement the concepts on daily everyday life. The learning itself is hoped to bring deeper meaning to student, provide a better learning condition through experiments, and hoped to help student generates a comprehensive understandings on important issues (Davison, 1995). STEM approach is a combination of science, technology, engineering, and mathematics in to a curriculum as a unit (Jones, 2008). Integrated approach of the STEM will help the students with analytical and probem solving aptitude to prepare them for real life working environment. Knowledge with applicable implementation on solving problems is the definition of scientific literacy. Scientific literacy defined as knowledge and skills required to identify problems, acquire new knowledges, explaining natural phenomena, and drawing conclusion based on presenting evidence.

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ment (PISA) is an international study designed and executed by *Organization for Economic Cooperation and Development* (OECD) as a means of international assessment regarding the efficacy of education system in preparing the students for real life dynamics. Of several PISA tests held, Indonesia consistently scored worrisome results. The 2012 testing saw Indonesia placed at the 64th out of 65 participants (OECD,2014). This result could be tied to several factor including the lack of learning media. Computer technology could be the answer to this problem. Computer technology has not been used to it's full potential as a learning media by the teacher.

The use of computer technology as learning media requires the teacher to play the role as a facilitator to improve the student's understanding on the subject matter (Kutluca, 2010). An application of computer based learning media is in the form of virtual lab. Virtual lab is a computer program designed to simulate the real life laboratory works and expriments (Keller, 2005). Acoording to Hampell (2001), virtual lab is a tool to achieve a high quality learning by providing virtual apparatus, algorithm, and other equipment in particular discipline.

Main component of virtual lab is: 1) laboratory setting and equipments; 2) computer set; 3) computer network; 4) virtual lab program; 5) partnership management and policy; 6) engineering division (Dillon, 2007). In this study the virtual lab used is based on offline platform, so point three is null.

According to experts, characteristics of virtual lab base education is as follows: a) creates novel knowledge, b) builds knowledge and internalizes informations, c) motivates and guides the students, d) registers student informations automatically and evaluates them, e) simulates experiments that are either dangerous and/or expensive, f) optimizes time consumption on learning process, g) improving student's academic achievements, h) improving student's conceptual understandings, i) specially suitable for children with visual learning style (Carnival, 2003; Keller, H.E&Keller, B.E., 2005; Jian, Brown, & Billet, 2005; Saleh, Mohamed, &Madkour, 2009; Dobrzanki&Honysz, 2010; Taskin&Kandemir, 2010; Gunhaart&Srisawasdi, 2012).

Virtual lab uses computer program to simulate series of experiments without physically doing them. It provides students with tools, material, and laboratory set vitually on the computer to carry experiments subjectively anytime and anywhere (Babateen^{+}, 2011). Virtual lab also enable students to simulates the laboratory works that are impossible to carry on real life. Virtual lab can help students to explore visualize abstract concepts in science application (Baser & Dumus, 2010). Some benefit of virtual lab are : 1) enable students to create alternative experiments because of the time and cost efficiency, 2), enable students to achieve understanding on macroscopic, submicroscopic, and symbolic level (Murniza, *et al.*, 2010), 3) provides dynamic representation of submicroscopic particle, 4) contibutes to a better understanding on chemical compunds, 5) strongly motivates students (Herga et al, 2014). Virtual lab can also improve conceptual thinking and investigation performance (Chien, et al, 2015)

Despite the overwhelming benefits, virtual lab has several disadavantages i. e: a) lack of physical interaction between hardwares, equipments, teacher, and students; b) the need of computer and specific tools; c) the need of technical expert staff, instructor, and curriculum expert to design and produce the lab; d) virtual lab can not enhance social and psychomotor skill as good as real lab should (Carnival, 2003).

Regardless of the disadvantages, virtual lab has the ability to bring the STEM learning closer to students through interesting activity social interaction (August, et al. 2011). Real life practice could not help build STEM skills, so virtual lab can provide a solution on this aspect. Based on above logical framework, a STEM virtual lab has been developed and the effectiveness on enhancing student's scientific literacy was examined.

METHOD

This study use the four stages educational research and development model with define, design, develop, and disseminate phase (Thiagarajan, *et al*., 1974). On define phase, problems from PISA 2012 testing were analyzed to identify content and context which will be build in to virtual lab. Analysis from PISA test the triangulated with curriculum analysis, in this case is the 2013 curricculum. Next step was to do literature research in order to define the concept of STEM.

Design phase consists of: making flowchart, storyboard, and user interface of the program. Develop phase is where the virtual lab was made by using adobe flash CS 6.0, which was then validated by media expert and teacher as the user. Disseminate phase saw the distribution of the virtual to end user to be implemented and tested. Trial was done at SMP IT Azkia Sukabumi. Two class with gender segregation was selected to examine the practicality of virtual lab developed by using one group pretest-posttest design

(Fraenkel *et al.*, 2011). The sample consist of 59 students, 29 from 7B class and 30 from 7D class.

RESULT AND DISCUSSION

Virtual lab was designed and developed based on the STEM concept (Zolman, 2012). The theme covered was water pollution from science subject. Pictures below is the user interface of STEM virtual lab developed.

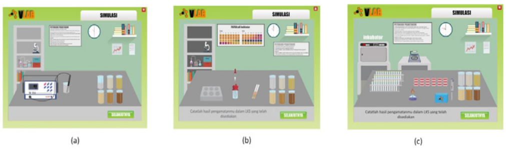


Figure 1. Screenshots of STEM virtual lab user interface; a). Turbidity experiment, b). pH value testing, c). Dissolved pathogenic bacteria examination

Scientific literacy framework referred here was established by *National Science Education Standards* (NSES) and *Organization for Economic Cooperation and Development* (OECD). Scientific literacy defined as an ability to employ the scientific knowledge and understandings of science in decision making process in real life scenario especially on the subject of health and sanitary, earth, environment, and technology.

The virtual lab developed exhibits experiments with three water pollution indicators: water turbidity as physical indicator, pH value as chemical indicator, and pathogenic bacteria as biological indicator. These indicators were selected to be included on the software because of these concepts are abstract and need to be made easy for students.

Characteristic of tecnology literacy implemented on this virtual lab was established by *National Assessment Governing Board* (NAGB), *International Society for Technology in Education* (ISTE), dan *International Technology Education* Association (ITEA). Author combines and integrates the characteristics proposed by mentioned professional organizations. Characteristic of technology literacy referred on developing this virtual lab is the use of advanced technology in learning, to help the students use, understand, investigate, dan solve problems with technology. Manifestation of technology.

Engineering literacy which also referred on this research was proposed by OECD and *Accreditation Board for Engineering and Technology* (ABET) as an ability to sistematically and creatively act on the guidance of scientific principles with practical use on product design, manufactures, and structural operations. One particular ability enforced by this virtual lab is sistematic and creative ability on scientific principles corridor. On this virtual lab students will be tasked to work systematically, organizing steps that has been randomized, as seen on Figure 3.

Figure 2. Virtual lab content intenalizes characteristics of technology literacy

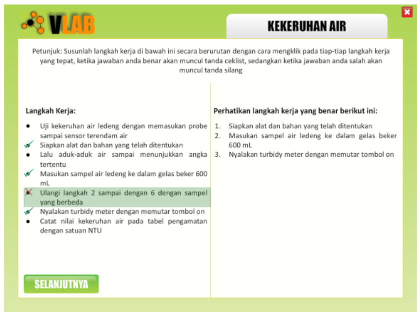
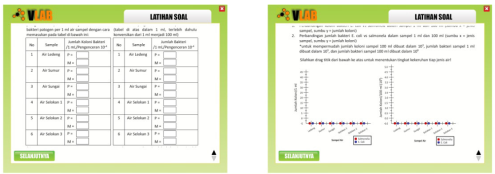


Figure 3. Manifestation of engineering literacy on virtual lab.

In Figure 3 we can two column with directions for student to organize the randomized work steps. Students should arrange the activities randomized in left column into correct order on the right column. In the process if student manage to arrange the activities correctly, checklist mark will appear on the left column. But if the students messed the order of the activities, a large red x will appear on left side to signify that the answer is not correct. In placing the steps of activities, students need to be careful as to not a mistake since the amount of clicks is measured. If the amount of click needed to arrane the activities is more than the amount of steps, the programs calculated it as mistake, thus reducing the point.

Mathematics literacy referred on developing this STEM based virtual lab is proposed by PISA and National Council of Teacher of Mathematics (NCTM) which states that mathematics literacy as an ability to identify, read, listen, creatively think, communicate, understand, and involved in mathematics and making informed judgement on certain situation. Mathematical skills enforced through this virtual lab are identification, reading, and communicating in the form of data generalization on table and graph. It manifested on the virtual as shown in Figure 4.



(a) (b)

Figure 4. Screenshots of virtual lab showcasing mathematics literacy characteristics, a). Generalizing data to table, b). Generalizing data to graph.

Mathematical skill integrated on the virtual lab in the form of data generalization skill into graph and table. This skill was trained in the vitual lab along with mathematical unit conversion skill. Data generalization training is included in the virtual lab posttest menu on every experiment section.

Validity check performed by media expert and science teacher declared the STEM based virtual lab developed to be of high quality and suitable to be used on learning process. Validity check from curriculum expert stated that the product falls in to "very good" category and is suitable to be used on science learning. Validation data is provided in table 1. This result conform to what is expected from a learning media which states that learning media should be able to facilitate the information exchange, transmit concepts, and help constructs meaningful learning to motivate the students as well as enhancing their science skill (Kutluca, 2010; Gundogdu, *et al.*, 2011).

Validation was done by two media expert, with satisfactory result. Virtual lab developed is found to be valid and suitable for science learning in the topic of water pollution, as shown in table 2. Judgement from expert determine the product is of high quality and attractive, provides interactive platform, coherent with the referred curriculum, and succesfully implement STEM concept. The virtual lab scores high result as media as it incorporates three important elements of mutimedia product i.e. voice, picture, and text. The vitual lab is found to be able to simulate the real laboratory experiment as also been stated by Keller at 2005. Authenticity of the experiments provided is kept to the highest with the embedding of particular equipment essential on real life practice such as turbidymeter on turbidity experiment simulation, pH indicators, and colony counter. This helps give the authenticity and resembling learning experience to the real life practice, which is also the case on Harms (1998) and Hamper's (2001) research.

Next step was to check the combination of scientific theme in the virtual lab. To ensure that biology, physics, and chemistry content are fused together in harmony, the virtual lab was validated by three independent experienced teachers from each discipline. Validators unanimously stated that the virtual lab developed is potential to motivate student, enhance their scientific literacy,

Table 1. Data recapitulation from STEM based virtual lab validation analysis by curriculum expert

Criteria	Score	Max Score	%	Category
Aspek kebenaran konsep	15	16	93.75	very good
Aspek kedalaman dan keluasan konsep	17	20	85.00	very good
Aspek peningkatan literasi sains	11	12	91.67	very good
Total	43	48	270.42	very good
Mean	14,33		90.14	very good

Table 2. Data Recapitulation from media expert validation of STEM based virtual lab

Criteria	Score (%)		Mean	Category
	Validator 1	Validator 2		
Design quality	88.89	8.,89	88.89	very good
Visual attraction	75	95	85,00	very good
Interactivity	79.17	100	89.58	very good
Coherency with curriculum	75	100	87.50	very good
Incorporation of STEM concept	75	87,5	81.25	very good
Mean	78,61	94,28	86.24	very good

stimulate them to learn actively, and train their thingking skills.

Validation from both curriculum expert, media expert, and science teachers declared that the product is of high quality. Experts validations are then supported by data from virtual lab implementation in the classroom. The use of virtual lab on learning process significantly improved student's scientific literacy. Improvements in science literacy are observed in content domain and competence domain in the scope of context domain, in this case is environmental context, as well as attitude domain. Both of the class tested showed improvements in scientific literacy level, but with different gain.

In content domain, topics included are water pollution, indicators of water pollution, components of water pollution, and effect of water pollution. Student's mastery over the science content is decribed in Table 4.

According to Table 4 above class 7b shows a better improvement on water pollution indicator at 57.89%, while class 7d scored highest at water pollution definition at 54.55%. Content with the lowest gain scored by class 7b was the water pollution definition at 40.74%, while class 7d scored the lowest in water pollution components at 10.93%. Recapitulation of student's science literacy improvements is described in figure 5.

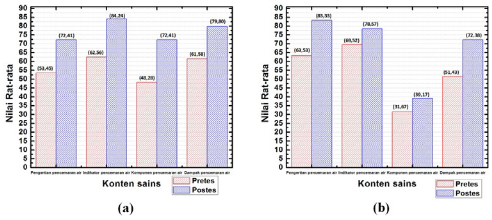


Figure 5. Student's scientific literacy before and after treatment with STEM based virtual lab (a) Class 7B dan (b) Class 7D

Table 3. Data Recapitulation of virtual lab validation by science teachers

Criteria	Score				Ideal score	%	Category
	Teacher 1	Teacher 2	Teacher 3	Total			
Curriculum coherency	14	16	16	46	48	95.83	Very good
Incorporation of STEM concepts	24	21	20	65	96	67.71	good
Virtual lab components	29	29	26	84	96	87.50	Very good
Easy of use on learning set	14	14	12	40	48	83.33	Very good
Usage potential on learning	26	26	24	76	96	79.17	Very good
				312	384	413.54	
						82.71	Very good

Table 4. Data recapitulation of student's scientific literacy improvements

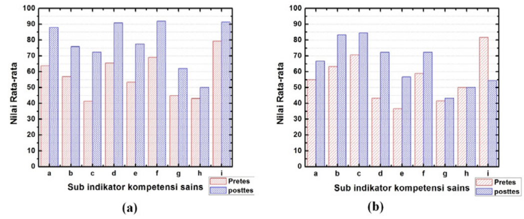
Content	Class (7B)				Class (7D)			
	Mean			Category	Mean			Category
	Pretest	Posttest	N-gain		Pretest	Posttest	N-gain	
Definition of water polution	53.45	72.41	40.74	Medium	63.33	83.33	54.55	Medium
Indicators of water pollution	62.56	84.24	57.89	Medium	69.52	78.57	29.69	Low
Components of water pollution	48.28	72.41	46.67	Medium	31.67	39.17	10.98	Low
Effects of water pollution	61.58	79.80	47.44	Medium	51.43	72.38	43.14	Medium
Mean	56.47	77.22	48.18		53.99	68.36	34.59	

Figure 5 shows that every science content saw improvement after treatment with STEM based virtual lab, with gain disparity for each content. Class 7b scored highest improvement on water pollution indicators, while the lowest gain was scored for water pollution definition.

Class 7d scored highest improvement on water poluution definition, and the lowest was for water pollution components. For science competence domain, science competence indicators studied were identification of scientific problems, explaining science phenomena, and using scientific prove, each with three sub indicators.

Data from table 5 shows that average improvement of identification of scientific problem, explanation of scientific phenomenon, and using scientific prove of class 7b in order are at 54,54%, 62,96%, and 35,23, while in class 7d the gain were 42,51%, 32,01%, and 27,27%. Total mean gain of class 7b is 50,91% while total mean of class 7d was 33,93%, both falls into medium category. There was a result disparity between classes with difference of 16, 93%, class 7b being the higher achiever.

For class 7b the highest improvement was scored on explaining scientific phenomenon indicator at 62.96% which falls in to medium category. Smallest improvement was scored on using scientific prove indicator at 35.23% at medium category. Highest improvement of class 7d was scored on identification of scientific problem indicator at 42.51%. It is understandable that using scientific prove indicator scored the lowest at both class because of student's unfamiliarity with the process of using and proving knowledges. Students used to be the at the receiving end of learning process, turning them in to passive learner, thus causing negative effect on their scientific proving ability. In the following histograms the scores of both classes is described.



Legends :
a)Recognizing issues with possible scientific explanation
b)Mengidentifikasi kata-kata kunci untuk mencari informasi ilmiah
c)Mengenal ciri khas penyelidikan ilmiah
d)Mengaplikasikan pengetahuan sains dalam situasi yang diberikan
e)Mendeskripsikan atau menafsirkan fenomena ilmiah dan prediksi perubahan lingkungan
f)Mengidentifikasi deskripsi, eksplanasi, dan prediksi yang tepat
g)Menafsirkan bukti ilmiah dan membuat serta mengomunikasikan kesimpulan
h)Mengidentifikasi asumsi, bukti dan alasan dibalik kesimpulan
i)Merefleksikan implikasi sosial dan perkembangan sains dan teknologi

Figure 6. Student's scientific literacy level in the scientific competence aspect before and after tretment with STEM based virtual lab. (a). Class 7b, (b). Class 7d

According to figure 6, the improvement of student's scientific literacy for scientific competence aspect shows the highest gain at indentifying, describing, explaining, and predicting subindicator at 74.07%. Lowest gain was scored on using scientific prove at 12.12%. Students have difficulties in using their knowledge in real life

Table 5. Data recapitulation of science competence domain improvement

Science competence indicators	Class 7b				Class 7d			
	Mean			Category	Mean			Category
	Pretest	Posttest	N-gain		Pretest	Posttest	N-gain	
Identification of scientific problems	54.02	78.74	54.54	Medium	63.01	78.16	42.51	Medium
Explaining scientific phenomenon	61.21	84.77	62.96	Medium	47.78	64.44	32.01	Medium
Menggunakan bukti ilmiah	61.21	70.69	35.23	Medium	65.83	70.83	27.27	Low
Mean	58,81	78,07	50,91	Medium	58.87	71.15	33.93	Medium

Table 6. Mean of student's scientific attitude

Indicators of Scientific attitude	Mean (%)							
	Class 7b			Category	Class 7d			Category
	Pretest	Posttest	N-Gain		Pretest	Posttest	N-Gain	
Supporting scientific inquiry	73.28	83.62	38.70	Medium	65.83	72.22	18.71	Low
Scientific curiosity	67.24	76.44	28.08	Low	65.61	75.83	29.73	Low
Responsibility on resources and environment	76.29	87.93	49.09	Medium	75.21	82.50	29.41	Low

scenario. Lowest score was found on using scientific evidence, identifying assumption, evidence and reasons behind conclusion at 0%.

Next domain examiened is scientific attitude domain. Scientific attitude measured consist of three indicators : 1) supporting scientific inquiry, 2). Scientific Curiosity , 3). Responsibility on resources and environment. Data from scientific attitude measurement of the student treated with STEM based vitua lab are described below.

Data from the table shows that there are improvements in student's scientific attitude after treatment with STEM based virtual lab. Generally, class 7b showed higher improvement than class 7d. Highest gain of class both classes was scored on the third scientific attitude indicators at 49. 09% for 7b and 29% for class 7d.

Considering the improvements of student's scientific literacy after the usage of STEM based virtual lab, we concluded that the product is very effective to be used in learning process. The use STEM based virtual lab on science learning is proven to be effective in enhancing student's scientific literacy, as shown by the test data. This result is at agreement with a research by Adolphus, et al. (2012) which states that ICT can help student in science learning by giving access to information, measuring, and analysis. The use of virtual can also stimulates and motivates student in learning because of the novelty and uniqueness of human-program interactions (Zumbach, et. al., 2006)

CONCLUSION

STEM based virtual lab of water pollution theme has been developed with high STEM characteristics, with satisfactory effectiveness. Validations from experts and users declared that the product is valid and of high quality. The product is a good alternative for water pollution experiments. The use of this virtual also score a significant gain on student's scientific literacy level as shown in the test data.

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