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EFFECTIVENESS OF VIRTUAL STEM LABORATORIES FOR ENHANCING HIGH SCHOOL STUDENTS' CREATIVITY AND STEM LITERACY

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ABSTRACT

The Virtual STEM Laboratory is a contextual experimental simulation learning tool that integrates science, technology, engineering, and mathematics (STEM) concepts. This study aims to investigate the Virtual STEM Laboratory's effectiveness in enhancing high school students' STEM literacy and creativity. STEM literacy is defined as the ability of a student to apply, identify, and integrate STEM concepts to solve complex problems and innovate in various areas. Meanwhile, creativity refers to the capability to generate novel and valuable ideas or solutions. The study used an experimental design with a control group to compare the effectiveness of the Virtual STEM Laboratory. In addition, students' STEM literacy and creativity were measured using posttest scores. The results showed that the experimental group had higher STEM literacy and creativity scores compared to the control group, which indicates the effectiveness of the Virtual STEM Laboratory. The study found that the Virtual STEM Laboratory improved STEM literacy as measured by the independent t-test and Kruskal Wallis test with a significance value of 0.000. This suggests that the experimental group had better STEM literacy skills than the control group. The Virtual STEM Laboratory was also found to be effective in enhancing student creativity as measured by the independent t-test with a significance value of 0.000, which implies that the experimental group generated more novel and valuable ideas than the control group. The study confirms the Virtual STEM Laboratory's effectiveness in enhancing high school students' STEM literacy and creativity. The Virtual STEM Laboratory is a valuable tool that can improve students' STEM literacy and creativity, thus contributing to their academic and professional development. Further studies can be conducted to explore the potential of the Virtual STEM Laboratory in enhancing other aspects of STEM education.

Keywords: Virtual STEM Laboratory, STEM Literacy, Creativity

INTRODUCTION

Chemistry learning is done by providing appropriate learning methods for each topic because the material in chemistry learning has its characteristics. Mastery of chemical concepts requires abstracting concepts, so it isn't easy to connect them [1]. Abstract concepts can be learned by conducting experiments or practicum in the laboratory because it is proven that learning in the laboratory positively impacts students' chemistry learning outcomes [2]. Providing direct experience to students through practical work in the laboratory can be one of the methods used in learning chemistry. Chemistry learning cannot be separated from the practicum carried out in the laboratory. The practicum is intended to develop chemical concepts, problem-solving abilities, improve scientific skills, and increase student motivation and interest in learning. The role of practicum in chemistry learning is strategic, facilitating the achievement of knowledge competence, skills, and the formation of students' character [3]. The primary goal of learning chemistry is that students can think and act based on their chemical knowledge [4]. With practicum, students will be trained to use tools in the laboratory, get to know chemicals, and better understand chemical concepts [5].

The laboratory is a supporting facility for chemistry learning activities. Laboratory activity makes a positive contribution to achieving learning goals. The laboratory can support learning if the teacher's ability [6,7], facilities, infrastructure, and laboratory management are adequately managed. However, the reality is that many schools still do not have proper laboratories for use in learning due to several problems [8]. This problem is one of the reasons why laboratories in schools cannot be used to support students in understanding chemistry. In addition, the constraints that cause chemistry practicums in schools are not always carried out, which are related to facilities and time constraints [9,10].

The shift of the learning paradigm from conventional learning to technology-based learning, especially ICT (*Information and Communication Technology*), has been felt by teachers. Furthermore, the 4.0 revolution era, where the industrial world trend combines automation technology with cyber, also positively impacts the world of education [11]. Thus, teachers must be able to adapt and adapt to ICT-supported learning. A virtual laboratory is a learning media that can be used as an alternative for practicum activities, primarily abstract concepts. Virtual laboratories can support and improve chemistry learning [12-14] and are considered an alternative pedagogical approach to overcome the limitations that exist in conventional laboratories. Virtual laboratories have proven effective in supporting practical-based chemistry learning [15-18]. Not only supporters of understanding chemistry but virtual laboratories can also improve students' learning skills and independence towards chemistry learning [19].

Not limited to understanding, skills, and independence, students must also have STEM literacy skills and creativity. Students can obtain STEM literacy through STEM-based learning. STEM literacy is a student's ability to identify, apply, and integrate science, technology, engineering, and mathematics concepts to understand complex problems and innovate in solving them [20]. The innovations made are related to the creativity of students. Student creativity can be increased through project-based learning, bringing up new ideas for solving real-life problems [21].

The virtual world can present STEM to students through exciting and socially oriented activities. Virtual STEM laboratories are media that are an alternative to conventional laboratories and can improve STEM literacy and student creativity [22,23]. For example, the virtual STEM laboratory in this study was used for the reaction rate material. The rate of reaction is one of the chemical materials considered to have many misconceptions about students' understanding.

METHODS

Research procedure

This research begins with identifying the problem through a literature study and field observations. The next stage is the selection of media and instruments to be used. The media used in this study is a virtual STEM laboratory on the reaction rate material. The next stage is the selection and testing of samples. In the sample selection stage, two classes at the second level were selected from the three test schools to serve as test samples. Finally, the sample testing phase was carried out using the design presented in Table 1.

Table 1 Sample test design

Group	Treatment	Posttest
Experiment	X1	O
Control	X2	O

X1 students use a virtual STEM laboratory at the end of the reaction rate lesson. X2 students did not use the virtual STEM laboratory at the end of the reaction rate lesson. The last stage of the research is data analysis of research results. At this stage, the data obtained from sample testing are analyzed using the right method.

Participants and Research Instruments

This research was conducted at three schools in Sragen Regency in 2021-2022. Two classes were taken from each school as experimental and control classes. Class selection is based on the Bartlett and T-test results using semester final test score data for XI students from each school. The total number of test students is 145.

The instrument used in this research is a written test. This test is carried out after students use the virtual STEM laboratory (for the experimental class) and after learning the reaction rate material (for the control class). The test instrument is a question that consists of two parts: the STEM literacy test and the creativity test. Before being used in this test, the instrument passed the validity and reliability test of the questions.

Analysis

The data obtained from the test are STEM literacy *posttest scores and* students' creativity *posttest scores.* The value data were analyzed to determine the effectiveness of the virtual STEM laboratory used. The effectiveness test was conducted using t-test analysis to determine the usefulness of the virtual STEM laboratory developed to increase STEM creativity and literacy in the reaction rate material. This test can be carried out if the data has been tested for normality and homogeneity with the data from the STEM creativity and literacy test results from the control and experimental classes that were sampled in this study.

RESULTS AND DISCUSSION

The data obtained in this study is quantitative in the form of *post-test scores* in a state. These values were tested and analyzed using SPSS 25 software. Before the trial, each class from each school must be tested for prerequisites for selecting experimental and control classes. The tests carried out are the Bartlett test and Levene's test to determine the homogeneity of the population that will be used as a sample. The data used is the value of the semester final test, odd semester 11th grade in each school. The results of the homogeneity test can be seen in Table 2.

Table 2. Prerequisite test results for class selection in each school

School	Test Technique	Value of Sig.	Information
School A	*Bartlett*	0.062	Homogeneous data
School B	*Bartlett*	0.195	Homogeneous data
School C	*Levene*	0.067	Homogeneous data

The homogeneity test in schools categories A and B use the Bartlett test because it has more than two groups, and the populations in each group are different. While for category C schools, the homogeneity test used Levene's test because there were two groups. Based on Table 2, it can be concluded that the class used as a sample in this study is homogeneous. Each school's class used in the study has the same variance.

Prerequisite Test

Before the effectiveness test, the data were first tested for prerequisites. Prerequisite tests carried out are the normality test and homogeneity test. The results of the prerequisite test can be seen in Table 3.

Table 3 Prerequisite test results to determine the effectiveness of the virtual STEM laboratory

School	Ability	Test Type	Test Technique	Value of Sig.	Information
School A	Creativity	Normality (K)	*Shapiro-Wilk*	0.066;	Normal data
		Normality (Ex)		0.068	Normal data
		Homogeneity	*Levene*	0.819	Homogeneous data
	STEM Literacy	Normality (K)	*Shapiro-Wilk*	0.198	Normal data
		Normality (Ex)		0.059	Normal data
		Homogeneity	*Levene*	0.060	Homogeneous data
B school	Creativity	Normality (K)	*Shapiro-Wilk*	0.111	Normal data
		Normality (Ex)		0.317	Normal data
		Homogeneity	*Levene*	0.050	Homogeneous data
	STEM Literacy	Normality (K)	*Shapiro-Wilk*	0.086	Normal data
		Normality (Ex)		0.319	Normal data
		Homogeneity	*Levene*	0.584	Homogeneous data
School C	Creativity	Normality (K)	*Shapiro-Wilk*	0.085	Normal data
		Normality (Ex)		0.079	Normal data
		Homogeneity	*Levene*	0.145	Homogeneous data
	STEM Literacy	Normality (K)	*Shapiro-Wilk*	0.065	Normal data
		Normality (Ex)		0.103	Normal data
		Homogeneity	*Levene*	0.022	Data is not homogeneous

The results of the prerequisite test in Table 3 show that STEM literacy and creativity data are normal and homogeneous in schools A and B. Therefore, the effectiveness of the two schools can be done using the t-test. However, for school C the

STEM literacy data is normal but not homogeneous, so to test the product's effectiveness at school C using a non-parametric test technique (Kruskal Wallis test).

Effectiveness Test

After doing the prerequisite test, the effectiveness test aims to determine the effect of using a virtual STEM laboratory in experimental and control classes. The effectiveness test in this study used two test techniques: a parametric test (*Independent t-test 2-tailed)* and a non-parametric test (Kruskal Wallis test).

The data was used to test the effectiveness of the post-test scores from each school. The results of the effectiveness test can be seen in Table 4.

Table 4. Product effectiveness test results from the three schools

School	Effectiveness Test	Test Technique	sig value.	Information
School A	Creativity	*Independent t-test 2-tailed*	0.000	The experimental class has better creativity than the control class.
	STEM Literacy	*Independent t-test 2-tailed*	0.000	The experimental class has better STEM literacy skills than the control class.
School B	Creativity	*Independent t-test 2-tailed*	0.000	The experimental class has better creativity than the control class.
	STEM Literacy	*Independent t-test 2-tailed*	0.000	The experimental class has better STEM literacy skills than the control class.
School C	Creativity	*Independent t-test 2-tailed*	0.000	The experimental class has better creativity than the control class.
	STEM Literacy	*Kruskal Wallis Test*	0.000	The experimental class has better STEM literacy skills than the control class.

Table 4 shows that the significance value obtained from each test is > 0.05, meaning that the experimental class is better than the control class. In school A, the significant value for STEM literacy is 0.000, which means that the STEM literacy of students in the experimental class is higher than the control class. The significant value for creativity is also 0.000, which means that the experimental class students' creativity is higher than the control class in school A. The School B effectiveness test results, where the significant value for STEM literacy and creativity is the same, 0.000. Finally, at school C, a significant value for STEM literacy through the Kruskal Wallis test of 0.000 means that the experimental class at school C had higher STEM literacy than the control class.

Discussion

This study measures the effectiveness of using a virtual STEM laboratory in learning reaction rate chemistry. The learning system that is carried out integrates technology in chemistry learning. The technology used is learning media in a virtual STEM laboratory created in flash media. The application can be used without installing it on a PC because it can be used directly on the web address. A virtual STEM laboratory is a learning medium that uses a computer program to simulate experiments oriented to the STEM domain. Experiments in this virtual STEM laboratory include animation and simulation so that students are interested in using it [24,25].

The virtual STEM laboratory is hoped to attract students' interest in using it because it uses experimental simulations that are used more contextually [26]. Experiments in virtual STEM laboratories are based on actual problems in daily life. The problems raised in the STEM virtual laboratory aim for students to innovate to solve the problems they face and increase their STEM literacy [27].

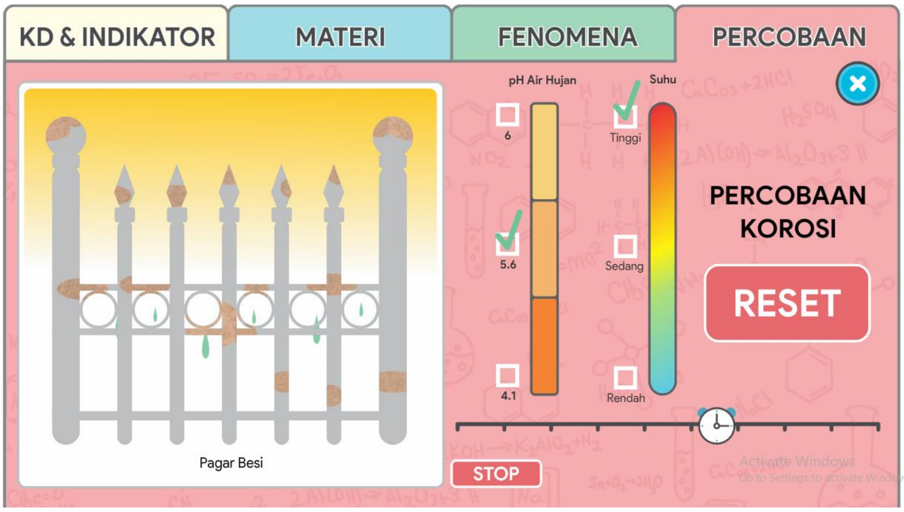

Figure 1. STEM Laboratory Corrosion experiment due to rainwater

The increase in STEM literacy of students who use virtual STEM laboratories can be seen from the answers to the STEM literacy posttest. The questions given have been adjusted to the STEM literacy indicators and have been validated by experts. For example, one of the indicator questions given is designing and engineering experiments on the effect of concentration on reaction rates [28,29]. In this question, the aspects of STEM literacy assessed are scientific, technological, and engineering. Therefore, answers from students must meet the criteria of each aspect, namely science, technology and engineering [30].

The virtual STEM laboratory plays a role in providing an overview of laboratory activities that can be accessed anywhere and anytime, making it easier in terms of accessibility. This Virtual STEM laboratory's activities help students master STEM literacy [8,9]—one of the indicators of STEM literacy in Science, Technology and Mathematics literacy. Mastery of Mathematics in collaboration with science and applying it in engineering by doing engineering is a brief description of STEM literacy [8]. Figure 1 shows one of the phenomena in daily life related to rusting of iron fences due to rainwater. This content can potentially increase STEM literacy skills by looking at the phenomenon of more acidic rainwater, making it corrode faster, and the temperature will increase the faster rust is done. From a scientific and mathematical point of view, this experiment requires calculations by determining the correct choice of pH and temperature so that corrosion can be slower

[31-33]. The engineering element appears in the way students will do the engineering so that rainwater does not easily corrode iron, students will look for additional references and show the efforts made in the worksheet provided. The experimental laboratory is very close to STEM because it combines elements of science, engineering, and mathematics, one of which is to do it directly and apply scientific principles appropriately so that they can carry out engineering and produce effective products [34].

They are following the statistical test in Table 4. Shows that the use of the Virtual STEM Laboratory is proven to increase students' STEM literacy skills. STEm literacy does not only focus on mathematical and scientific abilities but also engineering in the form of engineering. Engineering must start with understanding concepts and analyzing data mathematically to determine the right engineering [35]. The most widely used step to improve this is laboratory activity, which requires a lot of money and takes a long time to prepare [36]. The Virtual STEM Laboratory helps so that laboratory activities can be carried out anytime and anywhere. The application also trains engineering skills with students trying to try formulations so that a desired condition in Figure 2 is so that corrosion can be slowed down can occur.

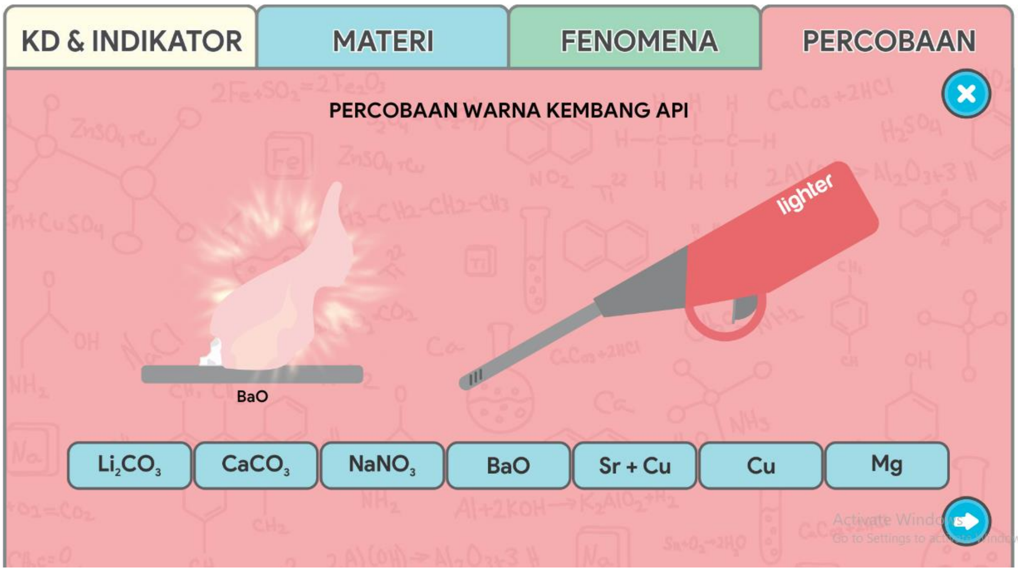

Figure 2. STEM Experiment on API Development

The first aspect of creative thinking is originality, students' ability to generate unusual, unique, or highly personal ideas or solutions [30]. The surface area theory will be considered in determining the reaction rate using the fireworks experiment. Powder and lump forms will produce different speeds. A larger surface area, such as powder, will make the reaction faster [37].

The second aspect of creative thinking is flexibility. This aspect refers to the ability to generate various ideas [38]. For example, predicting reactions that occur more quickly and are connected with collision theory will allow students to master various concepts. Increasing the number of collisions will make the reaction. Students can predict collision and surface area from the experiment in Figure 2.

The third aspect of creative thinking is fluency, students' ability to predict cause and effect and design solutions. In this case, after completing the practicum students are asked to determine the experimental procedure that is considered easy and environmentally friendly and to design an experiment from the procedure chosen. Again, the relationship between this ability and engineering in STEM goes straight; engineering an experiment with the ability to engineer a product has one thing in common—engineering experiments related to the mastery of the concept [39].

CONCLUSION

The data obtained was quantitative, in the form of post-test scores, and analyzed using statistical tests such as the Bartlett test, Levene's test, independent t-test, and Kruskal Wallis test. Before conducting the effectiveness test, the data were tested for prerequisites to ensure the sample was homogeneous and normal. The effectiveness test results showed that the experimental class, which used virtual STEM laboratories, performed significantly better than the control class, which did not use virtual STEM laboratories. The significant values obtained from the tests were all less than 0.05, indicating that the experimental class performed better than the control class regarding creativity and STEM literacy. The results of this study suggest that virtual STEM laboratories can be an effective tool for enhancing high school students' creativity and STEM literacy. This finding is significant as it indicates that virtual STEM laboratories can be a viable alternative to traditional laboratory setups, which are often costly and time-consuming. In addition, virtual STEM laboratories can provide students with opportunities to engage in hands-on learning activities and develop important skills such as problem-solving, critical thinking, and collaboration. Therefore, it is recommended that schools consider incorporating virtual STEM laboratories in their curriculum to enhance students' creativity and STEM literacy. However, further research is needed to investigate the long-term effects of using virtual STEM laboratories on students' academic performance and career readiness. The findings of this study highlight the potential of virtual STEM laboratories in enhancing high school students' creativity and STEM literacy. This study's results suggest that virtual STEM laboratories can provide students with hands-on learning opportunities and develop important skills that benefit them in their future careers.

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