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Application of Interactive Virtual Lab Media Based on a STEM Approach in Improving Students' Scientific Literacy and Learning Motivation

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Abstract: One of the developments in the world of education is using virtual labs as a medium for carrying out practical work. The aim of this research is to determine the application of using interactive virtual lab practicum media based on a STEM approach in increasing students' scientific literacy and learning motivation. The subjects of this research were students in the odd semester of the 2023/2024 academic year who took basic chemistry practical lectures on the topic of reaction rates. The research method uses a quantitative approach with a quasi-experimental design in the form of a one group pretest and posttest design. The instruments used in this research were a multiple-choice test to measure scientific literacy and a questionnaire to measure learning motivation. Data analysis in this study used descriptive statistics including n-gain and percentage calculations. Based on the results of data analysis, it was found that the increase in students' scientific literacy was 0.46 with moderate criteria. Scientific literacy skills have increased significantly in the aspect of explaining scientific phenomena by 82%. Student learning motivation also increased with an average of 77% before learning to 83% after learning.

Keywords: Learning Motivation; Practicum; Scientific Literacy; STEM; Virtual Lab

Introduction

In the 21st century there is very rapid world development, including economic, social, technological, communication, information and transportation aspects. To face these developments, it is necessary to develop life skills such as critical thinking, collaboration, problem solving, innovation, communication and creativity (Redhana, 2019). In the era of the Industrial Revolution 4.0, the need for scientific literacy and 21st-century skills, such as problem solving, critical thinking, and collaboration, is increasingly urgent. Higher education, as the vanguard in producing superior human resources, is required to present learning innovations that are relevant to the needs of the times. One effective approach to answering this challenge is the STEM (Science, Technology, Engineering, and Mathematics) approach, which has been proven to be able to improve scientific literacy while integrating technology into learning. However, the implementation of the STEM approach is often limited to conventional media, so it has not fully accommodated the needs of students in the digital era. Interactive Virtual Lab Media is present as an innovative solution that combines digital technology with STEM-based learning principles. This media offers interactive, flexible, and feature-rich experimental simulations, allowing students to learn

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independently while increasing their involvement in the learning process.

Advances in science and technology have had a significant impact on the field of education and are very important to survive in the competitive environment of the 21st century (Wardana et al., 2013). So that the nation's next generation can develop in the 21st century, namely being qualified, ethical, and able to operate on a global scale from the perspective of planning, capability, and capability, it is hoped that the quality of human resources will increase (Ramdani et al., 2021). Education in the 21st century is predicted to produce human resources who have a variety of skills for the 21st century, including scientific literacy (Menggo et al., 2019; Rios et al., 2020). Science learning that can increase students' scientific literacy is one strategy for improving human resource standards. Scientific literacy is very important for students to have because it helps understand and interpret scientific concepts and processes that occur in context (Amala et al., 2023). Scientific literacy does not only involve knowledge of concepts and theories, but also involves knowledge of procedures related to scientific investigation (Putri et al., 2023).

Science learning aims to help students be able to master knowledge about scientific regularities. This knowledge is obtained through a scientific process so that students have a scientific attitude that can be used to solve problems in everyday life. Science learning does not only include concepts, principles or theories, but there are also scientific processes that are taught through practicums, but this is rarely done by educators for several reasons, including no special time for practicums, inadequate tools and equipment. practical materials, and some do not understand how to work in the laboratory. Even though practicum plays an important role in science learning. (Adisendjaja and Romlah, 2009).

Obstacles in practicum can be overcome by using alternative learning media in the form of virtual labs. Virtual labs use computer programs to simulate a series of experiments without carrying out the activities directly. Virtual labs can strengthen practicum activities that cannot be practiced in real life, meaning that virtual labs can be an alternative practicum medium to replace real practicum if it is not possible to do so.

Virtual labs can support students to explore and visualize abstract concepts, especially in describing the application of knowledge (Baser & Durmus, 2010) and increase students' scientific literacy (Suanda, 2010). Apart from that, the use of virtual labs in learning has several advantages, including allowing students to produce other experimental work because it is effective in terms of time and cost, allows students to obtain visualization at the macroscopic, submicroscopic and symbolic levels, provide a dynamic presentation of the world of submicro particles, contribute to a better understanding of chemical constituents and a powerful motivational tool (Herga, Grmek & Dinevski, 2014). Virtual labs are also able to improve conceptual and investigative performance (Chien, Tsai, Chen, Chang & Chen, 2015). The virtual world can present Science, Technology, Engineering, and Mathematics (STEM) to students through interesting and socially oriented activities (August et al., 2011). Real practicums are less helpful in building STEM skills, which is why virtual labs were developed to build STEM skills.

Science, Technology, Engineering, and Mathematics (STEM) is an approach to the development of the world of education, especially in the science field. STEM education is formed based on the combination of several scientific disciplines into one unified new approach. The disciplines that are components of the STEM approach are science, technology, engineering and mathematics. The integration of several scientific disciplines into one unit is expected to produce graduates who are competent and qualified not only in terms of mastering concepts but also in applying them to life (Eva P. P et al., 2023). The STEM approach is a combination of science, technology, engineering and mathematics into one overall curriculum (Jones, 2008).

STEM education is a global movement in educational practices that integrates various integration patterns to develop quality human resources that meet the demands of 21st century skills. STEM-based science learning as a form of STEM education is compatible with the current curriculum system in Indonesia (Firman, 2015). The integration of this STEM approach will help students analyze and solve problems that occur in real life so that students are ready to work. The knowledge used in solving these problems is the definition of scientific literacy. Scientific literacy is an individual's scientific knowledge and the use of that knowledge to identify questions, to acquire new knowledge, to explain, to draw conclusions based on evidence.

Scientific literacy is the ability to use scientific knowledge in understanding and making judgments about nature and how it is changed by human activities. This also includes the ability to identify questions and develop conclusions based on existing data (Rohman et al., 2017). Using scientific knowledge to understand and make decisions about nature and how it is changing due to human activities is known as scientific literacy. This involves identifying questions and reaching all conclusions based on evidence (Afni et al., 2018; Al Sultan et al., 2018; Fuadi et al., 2020; Muzijah et al., 2020). Indonesia is a country with a low level of scientific literacy (Masithah et al., 2022; Ramdani et al., 2021).

Based on student performance in the PISA (Program for International Student Assessment) science literacy test, Indonesia is ranked in the bottom 10 countries, even though scientific literacy is the main indicator of the quality of a country's education system (OECD, 2014).

The novelty of this study lies in the application of Interactive Virtual Lab media based on the STEM approach to improve scientific literacy and student learning motivation simultaneously. This study not only assesses the effectiveness of the media, but also explores how the STEM approach can be optimally integrated into interactive learning technology. This research is important to answer the challenges of low scientific literacy and student learning motivation in Indonesia, which often become obstacles in mastering science and technology globally. In addition, this research is also expected to provide real contributions to the development of technology-based learning media that are relevant to the educational context in Indonesia.

Based on the results of observations made during the lecture process, it was found that students' scientific literacy was still low. One of the causes is low student motivation to learn, this results in learning outcomes that are not optimal. Different levels of learning when learning occurs, student attitudes such as curiosity, joy, responsibility, enjoyment of their work, and responses to work. The stimulus given by the teacher can be used to find out whether students are motivated (Sudjana, 2013).

Increasing student literacy is important in the learning process. To attract students to be interested and enjoy learning, this can be done by facilitating teaching materials such as interactive virtual lab practicum media based on a STEM approach. STEM offers many pedagogical strategies, including existing frameworks, methods, and approaches for using STEM in the classroom (Park et al., 2022). Through STEM education, students develop scientific and technological literacy, which is seen in reading, writing, observing, and practicing science. As a result, students are better prepared to live in society and solve problems related to STEM disciplines in everyday life (Mayasari et al., 2014). This is in accordance with previous research, finding that STEM-based virtual lab media to improve students' critical thinking skills are valid, practical and effective. (Sari, Rona Taula, et al., 2022). STEM learning can also improve student learning outcomes and motivation (Amdayani et al., 2022).

Student learning achievement can be influenced by several factors, including internal factors such as intelligence, talent, interest and learning motivation (Abdullah et al., 2021). One element that influences learning and achieving learning goals is learning motivation. Motivation is the driving force within a person that can generate, direct and become the basis for a person's behavior to achieve a goal (Glynn et al., 2009). Motivation is an important factor in the learning process which can have a positive impact on student learning outcomes (Safitri et al., 2023). Students' abilities and skills are directly proportional to their own motivation (Taupik et al., 2023).

By considering several things above, innovation is needed to overcome these problems by implementing interactive virtual lab practicum media based on a STEM approach to increase scientific literacy and student learning motivation.

Method

Quantitative research with an experimental approach is the methodology used. The type of research used is pre-Experimental. One-Group Pretest Posttest Design is the type of pre-Experimental used. This research was conducted at the Faculty of Teacher Training and Education (FKIP), HKBP Nommensen University, Pematangsiantar. This design uses a group of research subjects from a population that is not randomly selected (Boslaugh, 2008; Cohen et al., 2018). The sample for this research was selected using a purposive sampling technique using criteria such as lecturers who teach the same and equivalent student competencies. The subjects of this research were students in the odd semester of the 2023/2024 academic year who took basic chemistry practical lectures on the topic of reaction rates.

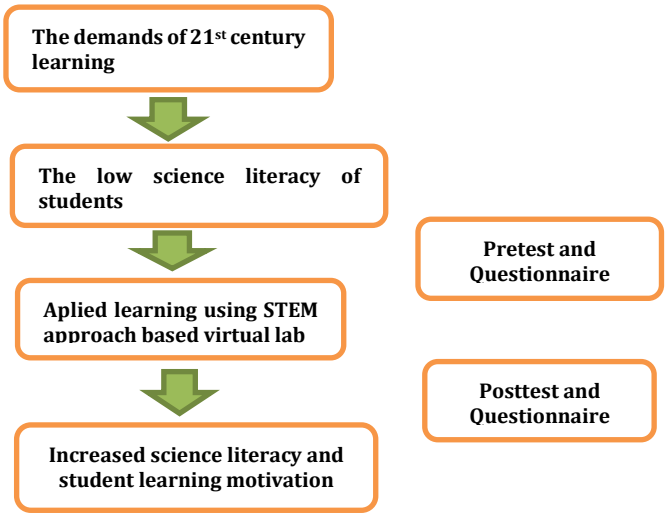

Figure 1. Chart of Research Stages

The instruments used in this research were test and non-test instruments. The test instrument used is a multiple choice test to measure scientific literacy, while the non-test instrument is a learning motivation

questionnaire. The criteria for scientific literacy scores are as shown in Table 1 (Purwanto, 2010).

The scientific literacy test developed refers to the PISA 2012 framework which is linked to STEM aspects. Research data was analyzed statistically and descriptive statistics including n-gain and percentage calculations. Increasing students' scientific literacy after learning using STEM-based interactive virtual lab practicum media is achieved by measuring the normalized average gain score (n-gain) on Equation 1(Hake, 1998).

Table 1. Criteria for Scientific Literacy Scores

Interval (%)	Criteria
86-100	Very high
76-86	High
60-75	Medium
55-59	Low
≤ 54	Very low

$$g = \left(\frac{\%(S_f) - \%(S_i)}{100 - \%(S_f)}\right) \quad (1)$$

Information:

g : normalized gain value
Sf : mean posttest score
Si : mean pretest score

According to Hake (1998), the normalized mean gain value can be interpreted as follows: (g) < 0.3 for the low category; 0.3 ≤ (g) < 0.7 for medium category; and (g) > 0.7 for the high category. The increase in student learning motivation was analyzed with descriptive statistics using a percentage formula. The analysis results are then classified into very high, high, medium, low and very low. The number of criteria scores (each item has a maximum score of 5 multiplied by the number of items 11 and the number of respondents (54 students) is used to assess the results of the motivation questionnaire. The percentage values can be interpreted as follows: 0–20% for very low, 21–40% for low, 41–60% for medium, 61–80% for high, and 81–100% for very high.

Result and Discussion

Increasing Scientific Literacy

The scientific literacy questions used in this research were prepared based on aspects of context, knowledge and competence. Overall, organic compounds are an aspect of context. For aspects of knowledge about reaction rate equations, factors that influence reaction rates and collision theory. Meanwhile, the competency aspect consists of explaining scientific phenomena, identifying scientific problems, and using scientific evidence.

After the test is completed based on the grid, the test is validated by material experts and it is declared suitable for testing. Validation is used to determine the level of feasibility of a test. The test questions are tested on students who have studied the reaction rate material and then analyzed to obtain validity, reliability, difficulty index and differentiability of the test questions. The test results were analyzed using the SPSS program. Reliability and validity tests on primary data test results were obtained from 35 respondents with an r table of 0.366 and a sig of 5%. In the validity test, of the 30 test questions tested, 23 questions were declared valid, so 20 questions were selected to be used as samples. used as pretest and posttest questions. Furthermore, the reliability test obtained a Cronbach's Alpha value of 0.815 so it was declared reliable. For the difficulty index test, the average questions used have a medium difficulty index. Followed by a differential test. sAll data contained in the corrected question item correlation table in the SPSS program shows a number greater than 0.3, so that all questions can be used because they have medium and high differential power.

After the test questions were declared suitable for use, a pretest was then carried out in two research sample classes, namely class 1 and class 2. After that, learning was given using interactive virtual lab practicum media based on a STEM approach. Then a posttest was carried out to determine the increase in students' scientific literacy after using interactive virtual lab practicum media based on a STEM approach. The average student pretest and posttest results on reaction rate material can be seen in Figure 2.

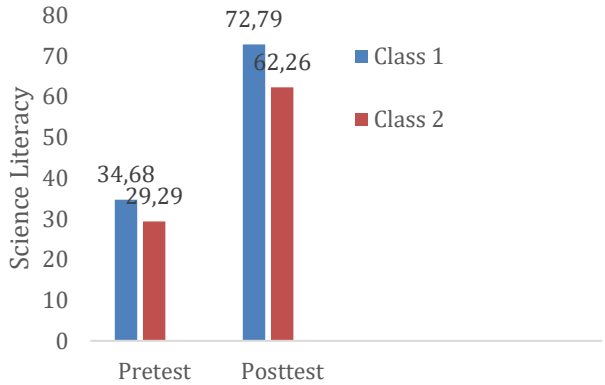

Figure 2. Average Student Pretest and Posttest Results

Figure 2 shows the change in the average value of the pretest and posttest. Overall the posttest score is higher than the pretest score. Class 1 has a higher average achievement and posttest results than other

classes. The lowest average pretest score was in class 2, and the lowest average posttest score was in class 2. Next, the scores obtained were analyzed to see the increase in scientific literacy assisted by interactive virtual lab practicum media based on a STEM approach using the n-gain formula. The results of the research sample can be seen in Figure 3.

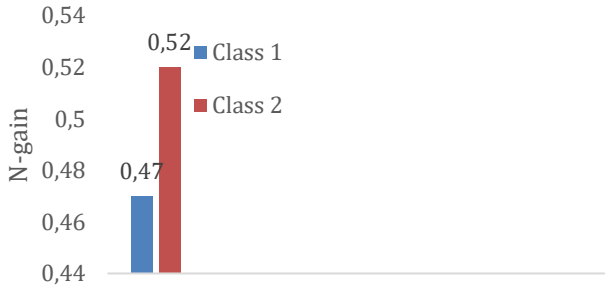

Figure 3. N-gain from Scientific Literacy

Figure 3 shows the average N-gain value obtained is 0.467 with medium criteria. Class 2 has the highest n-gain compared to class 1, namely 0.47. It can be concluded that the interactive virtual lab practicum media based on the STEM approach is effective in improving students' scientific literacy skills with moderate criteria. In accordance with research results (Dianti et al., 2023), the application of learning with a STEM approach, this approach has good effectiveness in increasing students' scientific literacy.

Similar research also obtained the same results that learning with a STEM approach had an effect on scientific literacy (Afriana, 2022). In line with research by Nilyani et al. (2023) which shows that STEM integrated science learning has an influence on scientific literacy. Research by Asri et al. (2021) who found an increase in posttest results compared to pretest after implementing learning with a STEM approach. This shows that learning with a STEM approach can improve the quality of the learning process, which will affect the quality of graduates (Zamista, 2018).

Scientific Literacy in Competency Aspects

Scientific literacy is a learning result obtained by students as a form of the knowledge they have and is used to solve real problems in life. Aspects of scientific literacy competency are explaining scientific phenomena, identifying scientific problems, and using scientific evidence. The average proportion of students' scientific literacy success in the competency elements as shown in Table 2.

Table 2. Average Percentage of Achievement of Science Literacy Competency Aspects

Aspect Competencies	Pretest (%)	Posttest (%)
Explaining Scientific Phenomena	51	82
Identifying Scientific Issues	49	73
Using Scientific Evidence	44	69

Table 2 shows that the average scientific literacy is still relatively low in the field of competency at the pretest or before learning, namely in the aspect of explaining scientific phenomena at 51%, identifying scientific problems at 49%, and using scientific evidence at 44%. This is in accordance with the research results of Afni et al. (2018) and Fuadi et al. (2020) which found that many students have low scientific literacy.

Based on research by Mawardini et al. (2015) stated that one of the factors in students' low achievement of scientific literacy is they're not being able to interpret data and information and draw conclusions. However, after the learning process was carried out using interactive virtual lab practicum media based on a STEM approach, the average student's scientific literacy increased. Scientific literacy increased significantly in the aspect of explaining scientific phenomena by 82% with high criteria. Meanwhile, the aspect of identifying scientific problems and using scientific evidence increased by 73% and 69% with medium criteria. Among the three aspects of scientific literacy competency, the aspect of explaining scientific phenomena is the highest aspect possessed by students.

Increased Learning Motivation

Data on student learning motivation was obtained from distributing questionnaires (pretest and posttest) given before and after using interactive virtual lab practicum media based on a STEM approach and analyzed using the n-gain test to see the increase in student learning motivation.

Motivation is something that encourages action, directs action towards achieving the desired goal and determines how fast or slow an action is (Hamalik, 2002). The learning motivation questionnaire instrument was prepared in the form of a Likert scale according to the indicators developed by Uno (2009), namely concentration, enthusiasm for learning, independence, readiness to learn, enthusiasm or encouragement and self-confidence. Questionnaires were given to 54 respondents with answer criteria of strongly disagree (STS), disagree (KS), disagree (TS), agree (S) and strongly agree (SS). The following are the results of the percentage of student learning motivation in each aspect before and after learning, which can be seen in Figures 4 and 5.

Based on Figure 4, it is found that students' learning motivation before learning using interactive virtual lab practicum media based on the STEM approach is on average still in the medium category, namely 77%. Based on the analysis of 6 indicators of learning motivation, high learning motivation was obtained in the aspects of readiness and enthusiasm for learning, while the other 4 indicators were still in the medium category.

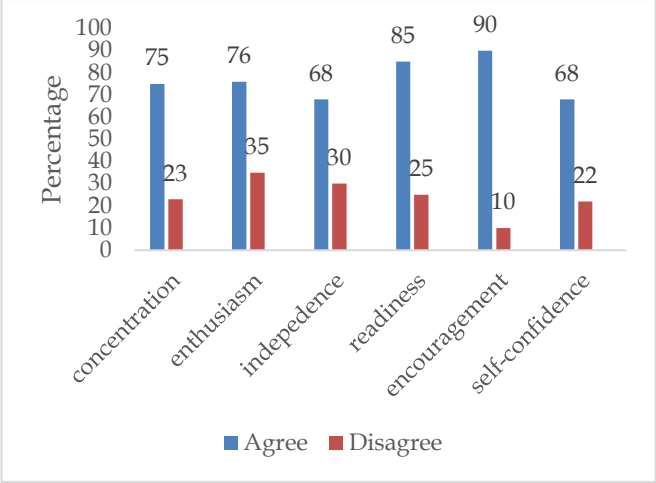

Figure 4. Percentage of Student Motivation Before Learning

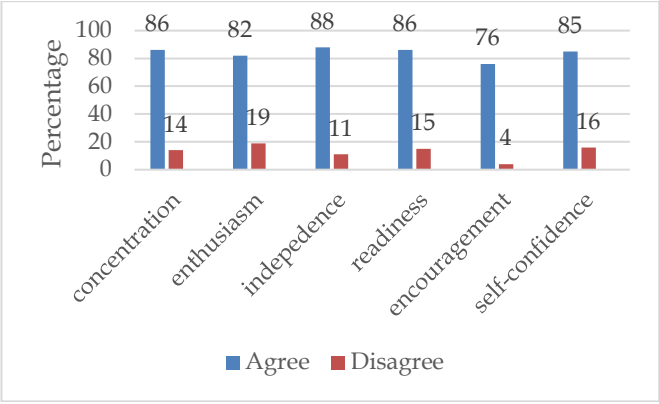

Figure 5. Percentage of Student Learning Motivation After Learning

Meanwhile, Figure 5 shows that students' learning motivation after learning using interactive virtual lab practicum media based on a STEM approach increased with an average percentage of 83% in the high category. It can also be seen that all indicators of learning motivation scored above 80% in the high category. Overall, every aspect of student learning motivation used in this research has increased after using interactive virtual lab practicum media based on a STEM approach on reaction rate material. This is in line with research by Ndoa et al. (2022) that there is an increase in student learning motivation in all measured learning motivation indicators.

Based on the data above, it can be concluded that interactive virtual lab practicum media based on the STEM approach can increase students' learning motivation on reaction rate material. This is in accordance with research proposed by Tseng et al. (2013) that the integration of STEM aspects can have a positive impact, especially in terms of problem solving and increasing motivation to learn and supporting future careers. The STEM approach has a positive effect on increasing learning motivation and facilitating problem solving skills of vocational school students in Taiwan (Chiang et al., 2016). Furthermore, Istyadji et al. (2022) stated that implementing learning that involves more active students can increase students' learning motivation.

Conclusion

Based on the results achieved, it can be concluded that the application of interactive virtual lab practicum media based on the STEM approach to reaction rate material can increase students' scientific literacy and learning motivation. Recommendations for further research can be applied in learning by analyzing critical thinking skills, creative thinking skills, collaboration skills or other variables.

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Author Contributions

EPP: conceptualizing and developing the research methodology; NFL: Conducting validation and revision; and GS: Conducting formal and resource analysis and conducting writing. All authors have read and approved the published version of the manuscript.

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Conflict of Interest

The researcher confirms that there is no conflict of interest associated with this research. This research was conducted independently, without any financial, professional, or personal influence from outside parties that could affect the results or

integrity of the research. The findings and conclusions are based entirely on the author's own analysis and work.

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