Volumes 11. Issue 2. 151-164 OCTOBER 2022

Jurnal ilmiah pendidikan fisika Al-Biruni
https://ejournal.radenintan.ac.id/index.php/al-biruni/index
DOI: 10.24042/jipfalbiruni.v11i2.12545

P-ISSN: 2303-1832
e -ISSN: 2503-023X

Virtual Lab Based on STEM Approach: Is It Effective to Enhance Students Concept of Temperature and Heat?

Muhammad Syukri[1 *], Mulia Rahmi[2], Saminan[3], Wiwit Artika[4], Tamil Selvan Subramaniam[5]

[1] Physics Education Department, Universitas Syiah Kuala, Banda Aceh, Indonesia
[2, 3] Science Education Study Program, Postgraduate at Syiah Kuala University, Banda Aceh, Indonesia
[4] Biology Education, FKIP, Universitas Syiah Kuala, Banda Aceh, Indonesia
[5] Faculty of Technical and Vocational Education, Universiti Tun Hussein Onn, Malaysia

**Corresponding Address: syukri.physics@unsyiah.ac.id*

Article Info

Article history:

Received: June 14, 2022
Accepted: October 16, 2022
Published: October 30, 2022

Keywords:

Physics concept understanding;
STEM approach;
Science lesson
Virtual lab.

ABSTRACT

This study aims to create a virtual lab in science-physics learning based on a valid, practical, and effective STEM-based virtual lab for junior high school students. The research was conducted using Research and Development. The research was conducted at SMP Negeri Unggul Tunas Nusa (junior high school). This research was carried out in the even semester of the 2021/2022 academic year. The subjects used in this study were students of class VII Tusa at SMPN Unggul Tunas Nusa in the academic year 2021/2022, totaling 29 students. The sampling technique used is random sampling. Based on the analysis, the average percentage assessment of all aspects is 87.89%, meaning the STEM-based virtual lab product is very feasible. The STEM-based virtual lab is assessed for teachers' and students' use. Practical criteria for teachers and students. The pretest means of student learning outcomes scored 24.57, while the posttest means after being applied to a STEM-based virtual lab scored 84.45. The average score of N-gain student learning outcomes is 0.80, which is high and able to improve student learning outcomes. The results of this study are expected to be used as an alternative for a teacher to improve student learning outcomes.

INTRODUCTION

Physicists study abstract and concrete concepts. Learning media make abstract, microscopic, and difficult-to-explain concepts easier and more engaging for students. In laboratory activities, media use can be done with real objects or tools. Using props, pictures, videos, and computer simulations in virtual lab can also provide learning experiences (Hadija et al., 2020).

The virtual lab is interactive multimedia-based software that can be used to simulate laboratory activities so that students seem to be doing it themselves (Munirudin & Madlazim, 2017). A virtual lab helps students understand complex topics by visualizing them. The virtual lab can also strengthen practice activities that can't be conducted in real, replacing the actual practice. If impossible.

Virtual lab are very important in learning physics because it teaches many abstract concepts. This virtual lab can help teachers apply abstract concepts to become more concrete.

Based on the results of observations at SMPN Unggul Tunas Nusa conducted by researchers, teachers have made various efforts in the teaching and learning process, both offline and virtual. The difficulties encountered during the practice are internal and external. Internal difficulties include an uncomfortable practice room and a lack of valuable equipment. In addition, skills,

How to cite Syukri, M., Rahmi, M., Saminan, S., Artika, W., & Subramaniam, T. S. (2022). Virtual Lab Based on STEM Approach: Is It Effective to Enhance Students Concept of Temperature and Heat?. *Jurnal ilmiah pendidikan fisika Al-Biruni, 11*(2), 151-164.

readiness, habits, attitudes, interest in practice, knowledge of practical material, and student motivation are internal factors that will affect practical activities. External difficulties can come from teachers' laboratory staff/teaching load, time allocation, manuals, and the school environment (Khaerunnisa, 2019). Practical activities in the laboratory are not always carried out properly due to obstacles such as limited facilities or difficulty in getting access to observe objects directly in the open. One of the science topics that can be studied theoretically and experimentally is temperature and its changes. The most dominant thing is that students still have difficulty reading the thermometer directly and determining the unit conversion.

Efforts to improve the quality of learning and success in carrying out practice in the laboratory must be equipped with adequate facilities and infrastructure, good management or service, and able to meet the expectations of students (Ilhamdi et al., 2020). Teachers need tips or efforts to find learning strategies that allow students to experience the material in everyday life directly. This kind of learning will more easily stick to the material in students' memories. The facilities and infrastructure at SMPN Tunas Nusa, such as computers/laptops, are adequate to make it easier for students to do practical learning using a virtual lab. The learning process so far will be more effective when using an approach that supports virtual lab in the learning process (Mauliza, 2018). The approach that can help implement the learning process is the STEM approach.

The STEM approach integrates technology/engineering design concepts into science/mathematics teaching and learning in the school curriculum. The implementation of learning will be more optimal if the STEM approach collaborates with simulations that provide learning simulations as a substitute for physics laboratories in schools (Hsu et al., 2017). A simulation suitable for use with the STEM approach is a virtual lab. Media that has been used are less helpful in building STEM knowledge. That is why virtual lab were developed to build STEM knowledge.

The development of a virtual lab in science-physics learning based on the STEM approach is very suitable for the learning process. Several studies have revealed that virtual lab with a STEM approach can improve the skills possessed by students, as well as their experiences and abilities in integrating STEM into the learning process (Fithri et al., 2021; Syukri et al., 2018). The STEM approach to learning is expected to produce meaningful learning for students through the systematic integration of knowledge, concepts, and skills. Some of the benefits of the STEM approach make students better able to solve problems innovators, inventors, independent, logical thinkers, and technological literacy (Sasmita et al., 2021; Syukri et al., 2018). The STEM approach positively affects the development of scientific process skills and improves the students' attitudes and motivation. A virtual lab based on the STEM approach is very impactful for students and has a significant effect, and is an alternative for students in developing the learning process in schools and the real world (Gunawan et al., 2015; Hamed & Aljanazrah, 2020; Ismail et al., 2016; Potkonjak et al., 2016; Rohim, 2020).

The use of virtual lab in online learning based on the STEM approach is the focus of research by researchers. The use of virtual lab will make it easier for students to explore their abilities (Jaya, 2013). The virtual lab developed by the researcher can be run via a computer/laptop. The virtual lab developed is designed or designed in STEM-based science-physics learning at SMP Aceh Barat Daya. The main characteristic of the virtual lab based on the STEM approach consists of development steps by applying the STEM approach and using the steps of the *engineering design process* (EDP) consisting of *ask*, *imagine*, *plan*, *create*, and *improve*.

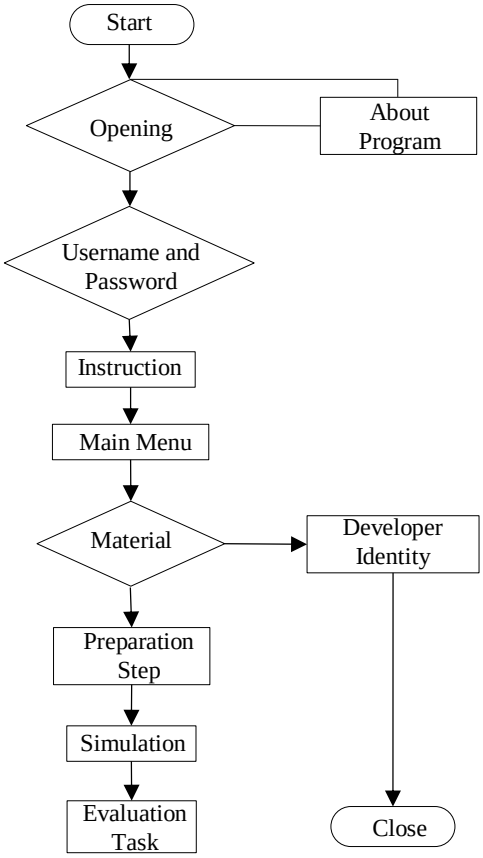
To date, many virtual lab developments have been carried out for the benefit of the physics learning process, including simulations of heat and its changes by (Alizkan et al., 2019); a simulation of Newton by (Baklanov et al., 2020); a simulation of heat and transfer by (Wibowo, 2016); simulation of oscillations by (Rizal et al., 2018); a simulation of physics in SMP/MTs by Sri (Wahyuni et al., 2022); a simulation of parabolic motion by (Lestari & Manstur, 2021); simulation of dry cell battery by (Wibowo et al., 2017). While the existing virtual lab is mostly just an ordinary virtual lab that does not use an approach and the virtual lab on temperature material and changes is only developed to see temperature changes when a thermometer is dipped in cold and hot water. Therefore, this study aims to create a virtual lab in science-physics learning based on a valid, practical, and effective STEM-based virtual lab for junior high School students. The virtual lab that was developed also makes it easier for students to use it because it does not require the internet or a special application to open the application.

METHODS

The research was conducted using Research and Development (R&D) research and development methods. This study's research and development model refers to the 4-D development model. This research was conducted at SMP Negeri Unggul Tunas Nusa, located in Ujung Padang, Susoh, Southwest Aceh Regency. This research was carried out in the even semester of the 2021/2022 academic year. The subjects used in this study were students of class VII Tusa at SMPN Unggul Tunas Nusa in the academic year 2021/2022, totaling 29 students.

In terms of development research procedures, we reveal the 4D model namely Define, Design, Develop, and Disseminate. The flowchart model chosen is the flowchart model for the simulation program. The resulting flowchart can be seen in Figure 1.

Figure 1. STEM-based virtual lab flowchart with the



theme of Temperature and Changes

Figure 1, it can be seen that the virtual lab starts with start and ends with Close. Students are required to enter the username and password provided. The following display is in the form of essential competencies, indicators, and learning objectives. The following display is instructions for using a STEM-based virtual lab. This is used to make it easier for students to use a STEM-based virtual lab. Furthermore, the main menu displays case material, preparation stage, and experimental simulation, which is equipped with evaluation questions on the experiment. Before closing the STEM-based virtual lab, the user can save the evaluation results of the questions that have been done.

This study uses instruments, namely virtual lab assessment sheets before being used in practical activities, teachers and student response questionnaires to test the practicality of virtual lab products based on

the STEM approach, and observation sheets on the implementation of virtual lab based on the STEM approach and effectiveness to measure student learning outcomes. Quantitative data analysis carried out included pretest and posttest data analysis. A good test is needed to get an idea of students' science skills. Before the description test is used, the questions are validated by expert lecturers. The revised expert lecturer validation results are tested to determine the validity, difficulty level, discriminatory power, reliability, and normality test.

RESULTS AND DISCUSSION

Define

One of the problems in schools today is the limited facilities and infrastructure that can facilitate students to build their knowledge independently. Based on the results of observations made at SMP Negeri Unggul Tunas Nusa, the learning process is still teacher-centered. The teacher only conveys the material without doing practicals in the laboratory. The material that the teacher entirely gives to students causes students not to be able to build their ability to find new concepts.

Based on interviews conducted with students, it is known that they are very rarely involved in the learning process that involves practice due to inadequate tools and materials and many tools and materials that cannot be reused, so it is necessary to develop a virtual lab based on a STEM approach that can facilitate them with various drawbacks and difficulties that exist in natural laboratories as a STEM approach can help students be more creative, technology literate and able to connect STEM education with the world of work (Morrison, 2006).

The results of the curriculum analysis show that SMP Negeri Unggul Tunas Nusa uses the 2013 curriculum as a reference for learning. At this stage, the researcher identifies the core competencies (KI) and essential competencies (KD) needed to develop a virtual lab in science-physics learning based on the STEM approach to temperature and change. The researchers set several indicators related to temperature and its changes based on this. The development of a virtual lab refers to the essential competencies and indicators of competency achievement, written in Table 1.

Table 1. Basic Competencies and Competency Achievement Indicators

Basic Competencies	Competency Achievement Indicators
3.4 Analyzing the concepts of temperature, expansion, heat, and heat transfer, also their application in everyday life, including mechanisms to maintain body temperature stability in humans and animals	3.4.2 Describe the different types of thermometers. 3.4.3 Determine the temperature scale by measuring the temperature using a thermometer
4.4 Conducting experiments to investigate the effect of heat on the temperature and shape of objects and heat transfer	4.4.1 Determine the temperature scale by measuring the temperature using a thermometer

According to the physics instructor's interview, kids only listen to what the teacher says during learning exercises. When pupils don't comprehend, they ask questions. Student answers questions. Not all are quiet or chat with their neighbors. Students can't answer physics issues on their own. Students can't understand physics because of this.

Students liked physics classes but often got bored with the material and lab work. They don't conduct much practical work in the lab due to obstacles like not enough tools and materials and rusted tools.

Based on the findings, STEM-based science and physics learning virtual lab products were created to help students complete experiments without being in the lab. This helps pupils comprehend physics by getting them moving.

Design

This virtual lab consists of several parts: a diamond display containing a username and password, a virtual lab display, essential competencies, core competencies, learning objectives, materials, simulations, developer identities, and evaluation questions. The pictures of some parts of the virtual lab design based on the STEM approach for more details are presented in Figure as follows:

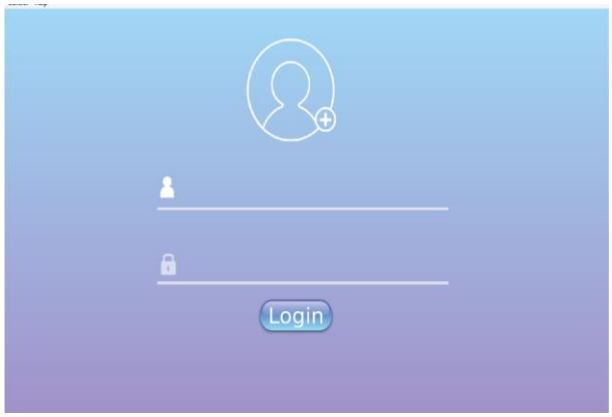


Figure 2. Diamond display

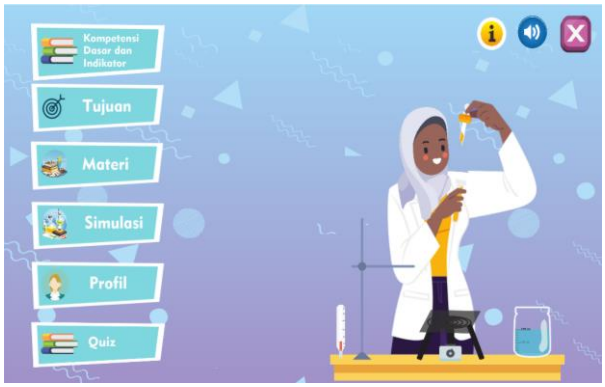


Figure 3. STEM approach-based virtual lab preview

Figure 4. Basic Competencies Menu Display and Indicator

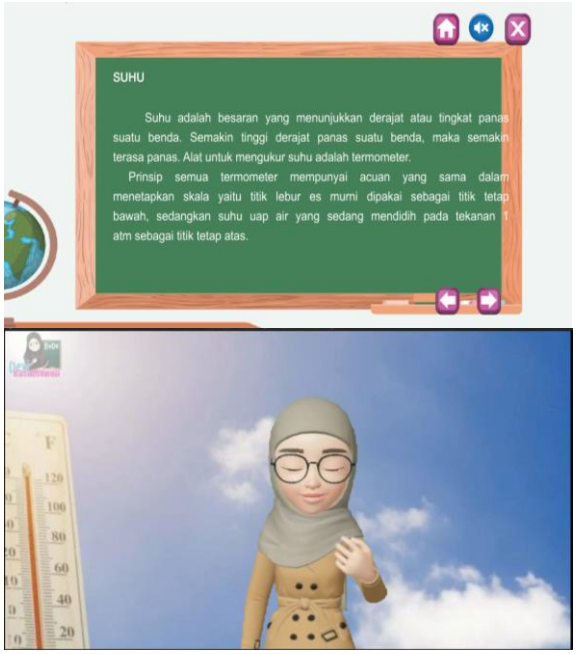


Figure 5. Material and video depicting the imagined aspect

Figure 6. Display of the case from the ask aspect

Figure 7. Display Menu Plan

Figure 8. Technology Characteristic Display

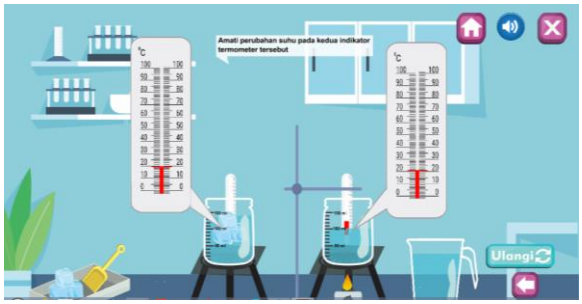


Figure 9. Display Aspect create

Figure 10. Display of mathematical characteristics

The constructed virtual lab design is evaluated utilizing an instrument in the form of a validation sheet questionnaire. The instrument is supplied to professional validators to assess the viability of the virtual lab before being given to students and teachers once the product is ready for testing. Questionnaire on a validation sheet to examine numerous areas of the virtual lab assessment, including presentation feasibility, content feasibility, and language and writing feasibility. A teacher and student response questionnaire was also created to assess the feasibility of implementing a virtual lab based on the STEM approach.

Develop

The validation stage is included in the virtual lab development stage and is delivered to three professional lecturers in the previously designed virtual lab.

The validator's recommendation is utilized as a reference for refining the product results to create a virtual lab that is based on a good STEM approach and can be used as a learning medium to improve student learning outcomes. Table 2 shows some suggestions and improvements:

Table 2. Validator suggestion revision

Section	Revision
Simulation	At the simulation stage in the virtual lab, where initially there were no case studies, a case study was added according to the material temperature and its changes
Engineering and plan stage	• At the engineering stage, different room temperatures were added, initially, the room temperature was 20^{o} C, and after being revised, room temperature variations were made • At the planning stage, which initially did not appear in the virtual lab, after being revised, a new page was added so that students could plan their picture of the practice to be carried out.
Improvements to indicators with sufficient scale	• Improved the appearance of the virtual lab to make it more attractive • Improve the instructions/steps of the virtual lab • Improved the virtual lab to make it easier for students to use • Improving aspects of technology

The main characteristic of this virtual lab based on the STEM approach consists of development steps by applying the STEM approach and using the steps of the engineering design process (EDP) consisting of ask, imagine, plan, create, and improve. The simulation section consists of three practical simulations based on solving problems in the case study. The developed virtual lab also makes it easier for students to use because it does not require the internet or a particular application to open the application. Virtual lab on temperature materials and changes are only developed to see temperature changes when a thermometer is dipped in cold and hot water.

Therefore, the developed virtual lab has novelty because the developed virtual lab practicum explains in more detail and makes variations so that students can compare the concept of temperature and its actual changes. After the virtual lab has been

revised according to the validator's suggestions, the validator fills out the virtual lab assessment sheet. The assessment is based on the feasibility of the presentation, the content, and the feasibility of language and writing. The results obtained can be seen in Table 3.

Table 3 . Virtual Lab Feasibility Test Analysis Results

No	Aspect	Percentage of Assessment Results from the Three Validators
1	Serving Eligibility	86.67% Very Eligibility
2	Content Eligibility	85.33% Very Eligibility
3	Language and Writing Eligibility	91.67% Very Eligibility
	Average Percentage of All Aspects	87.89%

Table 3 shows that the average percentage assessment of all aspects obtained is 87.89%, which means that the virtual lab product based on the STEM approach is classified in the very feasible category. The assessment is obtained from the average of the three aspects of the assessment. Suppose you look at each aspect, in terms of the feasibility of presentation, the feasibility of the content, and the aspect of language and writing. In that case, all three are included in the very feasible category. After going through a validation process by a validator consisting of three expert lecturers who showed that the virtual lab produced was very feasible, the virtual lab based on the STEM approach was tested on class VII Tusa students and teachers at SMPN Unggul Tunas Nusa.

Disseminate

Student learning outcomes were assessed using pretest and post-test questions in the form of essay questions consisting of 6 questions regarding the material temperature and its changes. The pretest-posttest data obtained were then processed and analyzed to see whether there was an increase in student learning outcomes before and after the implementation of the STEM-based virtual lab. To see the results of increasing student learning outcomes, researchers used the N-gain test with the help of SPSS. The data obtained have also been tested for normality using the Shapiro-Wilk test with the help of SPSS. The results of data processing or analysis of the average pretest-posttest scores obtained can be seen in Table 4.

Table 4 . Results of Data Processing Student Learning Outcomes

Average Value		Normality		N-Gain	Category
Pretest	Posttest	Sig. Pretest	Sig. Posttest	0.80	High
24.57	84.45	0.57	0.19		

The average scores students received on pre- and post-tests provide insight into the learning that took place for that particular student body. It is possible to see in the table that is located above that the average acquisition of the pretest test scores for student learning outcomes before the implementation of a virtual lab based on the STEM approach showed a score of 24.57; this demonstrates that students' knowledge of temperature material and its changes are still low. The purpose of the posttest, which was administered after the session, was to determine whether or not a STEM-based virtual lab led to an improvement in the learning outcomes of the class as a whole. The results of the posttest that were collected showed that the average value was 84.45. The Shapiro-Wilk test was carried out in SPSS to acquire the pre-test and post-test

scores. The data that was acquired has a normal distribution if the significant value is greater than 0.05, and vice versa. Given that the significant value acquired from the pre-test score was 0.57 and the post-test score was 0.19, it is possible to conclude that the pre-and post-test scores obtained by both students followed a normal distribution because they were greater than 0.05. A score of 0.80 was achieved in the high category of the N-gain test to investigate whether or not there was an improvement in the learning outcomes of students. This demonstrates an increase in the learning outcomes of students as a result of the implementation of a virtual lab that takes a STEM-based approach.

During the process of developing a virtual lab based on the STEM methodology, the observation sheet served as the primary tool for determining how effectively learning was put into practice. The observation sheet that was used had been used before and was taken from (Ismail et al., 2016). The outcomes of the investigations carried out are shown in the following table, which may be found in Table 5.

Table 5. Virtual Lab Implementation Observation Data Based on STEM Approach

No	Observer	Percentage (%)	Category
1	Observer 1	83.01 %	Very High
2	Observer 2		
3	Observer 3		
4	Observer 4		

Based on table 5, it can be seen that the results of the observation of the virtual lab based on the STEM approach obtained an average percentage of 83.01%, with a very high category. The high level of student activity is because students are very actively involved in the learning process during the learning process using a virtual lab based on the STEM approach. Learning activities using a virtual lab based on the STEM approach indirectly students understand the use of computers in terms of the development of students to be technology literate.

Based on the results of observations observing the virtual lab activities based on the STEM approach of students during the learning process, the results obtained can support increasing students' abilities to the concept of temperature and its changes, which are measured using students' learning outcomes tests. Based on the test analysis results, there was an increase in the pretest-posttest as seen from the N-gain score of 0.80, and was in the very high category (Table 5). The results obtained can be said that the virtual lab based on the STEM approach is very well used as a learning medium to improve student learning outcomes.

Based on the results of the analysis that has been done, students give very practical results to the virtual lab based on the STEM approach that has been developed. It is shown that the questionnaire score obtained is 96.15 and is in the very practical category. This shows that students are very enthusiastic and very interested in learning using a virtual lab based on the STEM approach to the concept of temperature and its changes. (Kurniasari et al., 2020) also conveyed this, who said that the virtual lab practicum media was instrumental in supporting practical learning. Using a virtual lab based on the STEM approach, students also have a guide in carrying out practicals to increase students' creativity. So, it can be concluded that the virtual lab based on the STEM approach is practical to apply in learning.

Based on the results of the analysis obtained from the teacher's response questionnaire, it was found that the teachers' response questionnaire gave very practical results to the virtual lab based on the STEM approach that was developed. The questionnaire results obtained in the practicality test of the teachers' response questionnaire of 3.31 were then matched with the interpretation of the teachers' response in table 3.8 so that it was included in the very practical category. Thus, the developed virtual lab can be used by the teachers as a

learning medium to improve student learning outcomes.

Discussion

The 4D development model (Thiagarajan et al., 1974) was selected as a reference for this research because it has a systematic and more uncomplicated stage to generate a decent product. This choice was made based on the research results that have been carried out. Overall, this decision was made. The generated product has been put through the testing phase to determine its feasibility, which includes the level of validity, practicality, and efficacy, and actions to revise the product to produce better versions of it, which are currently in the stages of development. Therefore, it is generally accepted that products for the virtual lab that is based on the STEM methodology can successfully be built utilizing 4D models.

The validity of this study can be found in the validity of presentation, as well as the feasibility of the material, as well as the feasibility of the language and writing. After passing through the validation process, the results of the process analysis are used as guidance for updating the product (Rokhim et al., 2020). According to the findings of the evaluation, the score on the presentation feasibility indicator is 86.67 percent, the score for the content feasibility indicator is 85.33 percent, and the score for the language and writing eligibility is 91.67 percent. As a result, the product, which has undergone multiple rounds of changes, has been deemed to be very genuine. Both the presentation and the content of quality educational media are indicators of its value as a teaching tool (Nurrita, 2018). According to the findings of (Muchson et al., 2018), the percentage of virtual lab feasibility ranges between 81 to 100, indicating that the development of a virtual lab can be considered to be very practical for use in educational settings. Therefore, the presentation of all of the information and media in a unified unit serves to support and strengthen each other as we create this product.

The findings of a user or user evaluation might provide insight into the practicability of a product. If the respondent indicates that the product generated may be implemented in the field and the level of implementation of the product falls into the "good" category, then the product that was developed might be considered to have some degree of practicality (Haviz, 2016). The average score that was attained by all 29 students was 96.15, and the score that the instructor awarded was 3.31. The score is understood to be an effective evaluation criterion for both the responses of the instructor and the pupils (Riduwan, 2009). In a pedagogical sense, the newly generated medium is incredibly helpful in supporting practical learning (Rokhim et al., 2020). Therefore, it is possible to conclude that the product in the form of a virtual laboratory that takes an approach based on STEM is stated to be highly useful in its application.

The efficiency can be observed in the research, which demonstrates that the results of the post-test scores on the question indicators are greater than the pretest scores that were acquired. This suggests that effect was achieved. This demonstrates that the implementation of a virtual lab centered on STEM principles, which has been carried out, is very effective in enhancing the learning results for students. This adheres to (Mauliza, 2018) theory, which argues that the virtual lab can be successfully implemented in a setting where all aspects are carried out. This follows the logic of the theory. Students learning results and attitudes can be significantly improved by the use of the virtual lab.

The difference in scores between the pre-test and the post-test may be attributable to an increase in student interest or a new learning environment that inspires students to feel more passionate about carrying out virtual laboratories based on the STEM approach. Students feel more at ease and are exposed to more engaging content while they

are learning with the help of a virtual lab that is based on the STEM approach. This adheres to (Junaidi et al., 2016) idea, which claims that establishing a virtual lab in which students believe that the learning carried out adds a new subtlety and stimulates them to understand physics.

When using a virtual lab that is based on the STEM approach, students have an easier time understanding temperature-sensitive material and the changes that it undergoes. This can lead to improved learning results. Students have the opportunity to be actively involved in the learning process, which enables them to rapidly develop their abilities with the components contained in a virtual lab based on a STEM approach. This approach includes aspects of science in the form of knowledge and understanding of concepts, as well as aspects of technology in the form of the capability to use technology in the use of virtual tools. Lab, engineering in the form of systematic skills in compiling work stages sequentially, and mathematics in the form of students' abilities in generalizing data and unit conversion. These are the three areas that will be covered in this unit. (Ismail et al., 2016) theory, which claims that a virtual lab based on a STEM approach comprises four skills, namely science, technology, engineering, and mathematics, can be used in this situation. This is by (Ismail et al., 2016) theory. Because the presence of these four competencies will generate curiosity among the students, it will lead to increased interest in the lessons that are being offered by the teacher. Recognize the students.

Students engage in an in-depth exploration of each practical step in the virtual lab as part of the learning process. The focus of their investigation is on the idea of temperature and how it varies. They can locate and comprehend the content in the virtual lab very fast, which increases the students' level of interest and motivation. According to (Nolen & Koretsky, 2018), the use of a virtual lab had a seamless impact on the activities that students participated in throughout their practice experiences. This finding is consistent with what was stated by (Nolen & Koretsky, 2018). This is also backed by research, which suggests that the value of learning outcomes utilizing virtual laboratories shows a value of 49 percent. This value indicates that virtual lab are effectively used to increase student learning outcomes. According to the findings of the study done by (Herga et al., 2016), making use of a virtual lab that offers visualization can be an effective technique to pique the attention of students in the process of learning a topic that is generally regarded as being dull.

Following the findings of the investigation into the N-gain test, all things considered, there was an increase in the number of students both before and after they were administered a test that fell into the high category. According to (Rissanen, 2014) theory, which claims that STEM-based learning can increase students' skills relatively rapidly and make it easier for students to understand a learning material, this finding is consistent with that idea. In addition, according to (Permanasari, 2016), education centered on STEM subjects can teach students how to apply the knowledge they gain to the process of design, which is a kind of problem-solving that is tied to both the environment and technology.

Overall, student learning outcomes using a virtual lab based on the STEM approach are valid, practical, effective to use, and appropriate to be applied in schools following the applicable curriculum and are one of the 21st-century characteristics regarding the use and utilization of technology. Following the research, (Dewi et al., 2019) states that the virtual lab based on the STEM approach is very feasible to use and can be applied to learning. With various activities carried out based on the virtual lab based on the given STEM approach, it can make it easier for students to understand the temperature material and its changes so that when given a test, students will be easier to complete and the results obtained will be higher than the previous results.

Based on the research results obtained, the virtual lab based on the STEM approach can be used as a learning medium for educators to improve student learning outcomes. Interest in a virtual lab based on a STEM approach can increase students' motivation by attracting their attention, maintaining their attention, and creating involvement in the learning process (Smaldino et al., 2011). So, the existence of a virtual lab based on the STEM approach can help students more easily understand and discover new concepts by being directly involved in the discovery of new concepts. Virtual lab based on the STEM approach also encourages students to be more proficient in using technology, which is a form of technology-centered change in society 5.0. As with the virtual lab based on the STEM approach, students are more required to play an active role in generalizing and constructing their knowledge so that students better understand the experiment. Thus, a virtual lab based on the STEM approach can help students improve learning outcomes (Permanasari, 2016).

CONCLUSION AND SUGGESTION

This study resulted in the creation of a virtual lab based on a STEM approach to the concept of temperature and its variations. The construction of a virtual lab based on the STEM approach was developed and validated for validity by a validator consisting of three experts. The virtual lab product based on the STEM approach had an average percentage assessment of 87.89 percent, which places it in the extremely feasible category.

Teachers and students are given practicality, which results in very practical criteria. This may be observed in the value of the teachers' questionnaire, which received a score of 3.31 in the extremely practical category, and the students' response questionnaire, which received a score of 96.15 in the same category.

The virtual lab, which uses a STEM approach, is also assessed. The N-gain average score of student learning outcomes shows an improvement in learning outcomes of 0.80, which is in the high category and is very useful to implement since it can improve student learning outcomes.

AUTHORS CONTRIBUTION

MS constructing and reviewing the literature. MR, S reviewed the literature and edited the manuscript. MS, S, and TSS edited the manuscript. All authors read and approve the final manuscript.

REFERENCES

Alizkan, U., Suherman, A., & Wibowo, F. C. (2019). Pengembangan virtual physics laboratory (VPL) pada konsep perpindahan kalor. *Prosiding Seminar Nasional Pendidikan Fisika Unitirta*, *2*(1), 226–230. https://jurnal.untirta.ac.id/index.php/sendikfi/article/view/9727

Baklanov, S., Stefanova, M., & Lupuleac, S. (2020). Newton projection method as applied to assembly simulation. *Optimization Methods and Software*, *37*(2), 577–604. https://doi.org/10.1080/10556788.2020.1818079

Dewi, A., Tika, N., & Suardana, I. N. (2019). Komparasi praktikum riil dan praktikum virtual terhadap hasil belajar kimia siswa SMA pada pembelajaran larutan penyangga. *Jurnal Pendidikan Kimia Indonesia*, *3*(2), 85–93. https://doi.org/10.23887/JPK.V3I2.21236

Fithri, S., Pada, A. U. T., Artika, W., Nurmaliah, C., & Hasanuddin, H. (2021). Implementasi LKPD berbasis STEM untuk meningkatkan keterampilan berpikir kritis peserta didik. *Jurnal Pendidikan Sains Indonesia (Indonesian Journal of Science Education)*, *9*(4), 555–564. https://doi.org/10.24815/JPSI.V9I4.20816

Gunawan, G., Harjono, A., & Sahidu, H. (2015). Pengembangan model

laboratorium virtual berorientasi pada kemampuan pemecahan masalah bagi calon guru fisika. *Seminar Nasional Fisika Dan Pendidikan Fisika (SNFPF) Ke-6 2015*, *6*(1), 232–237. https://www.neliti.com/id/publications/173119/

Hadija, B. S., Anas, M., & Tahang, L. (2020). Penerapan metode praktikum untuk meningkatkan keterampilan proses sains dan hasil belajar IPA fisika peserta didik pada materi pokok getaran dan gelombang kelas VIII SMP Negeri 2 Bungku Selatan. *Jurnal Penelitian Pendidikan Fisika*, *5*(1), 19–27. https://doi.org/10.36709/JIPFI.V5I1.10481

Hamed, G., & Aljanazrah, A. (2020). The effectiveness of using virtual experiments on students' learning in the general physics lab. *Journal of Information Technology Education: Research*, *19*(1), 977–996. https://doi.org/10.28945/4668

Haviz, M. (2016). Research and development; Penelitian di bidang kependidikan yang inovatif, produktif dan bermakna. *Ta'dib*, *16*(1), 28–43. https://doi.org/10.31958/JT.V16I1.235

Herga, N. R., Cagran, B., & Dinevski, D. (2016). Virtual laboratory in the role of dynamic visualisation for better understanding of chemistry in primary school. *Eurasia Journal of Mathematics, Science and Technology Education*, *12*(3), 593–608. https://doi.org/10.12973/EURASIA.2016.1224A

Hsu, Y. S., Lin, Y. H., & Yang, B. (2017). Impact of augmented reality lessons on students' STEM interest. *Research and Practice in Technology Enhanced Learning*, *12*(1), 1–14. https://doi.org/10.1186/S41039-016-0039-Z/TABLES/4

Ilhamdi, M. L., Santoso, D., & Astuti, S. P. (2020). Penerapan metode problem based learning untuk meningkatkan hasil belajar biologi mata pelajaran lintas minat. *Jurnal Pijar Mipa*, *15*(2), 135–139. https://doi.org/10.29303/JPM.V15I2.1699

Ismail, I., Permanasari, A., & Setiawan, W. (2016). STEM virtual lab : An alternative practical media to enhance student's scientific literacy. *Jurnal Pendidikan IPA Indonesia*, *5*(2), 239–246. https://doi.org/10.15294/JPII.V5I2.5492

Ismail, I, Permanasari, A., & Setiawan, W. (2016). Efektivitas virtual lab berbasis STEM dalam meningkatkan literasi sains siswa dengan perbedaan gender. *Jurnal Inovasi Pendidikan IPA*, *2*(2), 190–201. https://doi.org/10.21831/JIPI.V2I2.8570

Jaya, H. (2013). Pengembangan laboratorium virtual untuk kegiatan paraktikum dan memfasilitasi pendidikan karakter di SMK. *Jurnal Pendidikan Vokasi*, *2*(1), 81–90. https://doi.org/10.21831/jpv.v2i1.1019

Junaidi, J., Gani, A., & Mursal, M. (2016). Model virtual laboratory berbasis inkuiri untuk meningkatkan keterampilan generik sains siswa MA. *Jurnal Pendidikan Sains Indonesia (Indonesian Journal of Science Education)*, *4*(2), 130–136. https://jurnal.unsyiah.ac.id/JPSI/article/view/7590

Khaerunnisa, F. (2019). Evaluasi penerapan blended learning pada pembelajaran bahasa Arab di SMPIT Ibadurrahman: Studi kasus di kelas VII akhwat. *ALSUNIYAT: Jurnal Penelitian Bahasa, Sastra, Dan Budaya Arab*, *2*(2), 95–108. https://doi.org/10.17509/alsuniyat.v2i2.24808

Kurniasari, A., Pribowo, F. S. P., & Putra, D. A. (2020). Analisis efektivitas pelaksanaan belajar dari rumah (BDR) selama pandemi covid-19. *Jurnal Review Pendidikan Dasar : Jurnal*

Kajian Pendidikan Dan Hasil Penelitian, *6*(3), 246–253. https://doi.org/10.26740/JRPD.V6N3.P246-253

Lestari, P. D., & Manstur, J. (2021). The influence of the online PhET simulation-assisted using direct instruction on student's conceptual understanding of parabolic motion. *Journal of Physics: Conference Series*, *2126*(1), 1–7. https://doi.org/10.1088/1742-6596/2126/1/012013

Mauliza, N. (2018). Pengaruh laboratorium virtual terhadap hasil belajar dan sikap siswa dalam pembelajaran kimia. *Prosiding Seminar Nasional Mipa IV*, 286–291.

Morrison, J. S. (2006). Attributs of STEM education: The student the school, the classroom. *Teaching Institute For Essential Science*, 1–7.

Muchson, M., Munzil, M., Winarni, B. E., & Agusningtyas, D. (2018). Pengembangan virtual lab berbasis android pada materi asam basa untuk siswa SMA. *J-PEK (Jurnal Pembelajaran Kimia)*, *4*(1), 51–64. https://doi.org/10.17977/um026v4i12019p051

Munirudin, L., & Madlazim, M. (2017). Pengembangan lembar kerja siswa berbantuan laboratorium virtual dan media xampp fisika untuk meningkatkan hasil belajar siswa SMP pada materi matahari sebagai bintang. *IPF: Inovasi Pendidikan Fisika*, *6*(2), 10–15. https://ejournal.unesa.ac.id/index.php/inovasi-pendidikan-fisika/article/view/21718

Nolen, S. B., & Koretsky, M. D. (2018). Affordances of virtual and physical laboratory projects for instructional design: Impacts on student engagement. *IEEE Transactions on Education*, *61*(3), 226–233. https://doi.org/10.1109/TE.2018.2791445

Nurrita, T. (2018). Pengembangan media pembelajaran untuk meningkatkan hasil belajar siswa. *MISYKAT: Jurnal Ilmu-Ilmu Al-Quran Hadits Syari Ah Dan Tarbiyah*, *3*(1), 171–210. https://doi.org/10.33511/MISYKAT.V3N1.171

Permanasari, A. (2016). STEM Education: Inovasi dalam Pembelajaran Sains. *Seminar Nasional Pendidikan Sains*, 23–34.

Potkonjak, V., Gardner, M., Callaghan, V., Mattila, P., Guetl, C., Petrović, V. M., & Jovanović, K. (2016). Virtual laboratories for education in science, technology, and engineering: A review. *Computers and Education*, *95*(1), 309–327. https://doi.org/10.1016/j.compedu.2016.02.002

Riduwan, R. (2009). *Belajar mudah penelitian untuk guru-karyawan dan peneliti pemula* . Alfabeta. https://opac.perpusnas.go.id/DetailOpac.aspx?id=718981

Rissanen, A. J. (2014). Active and peer learning in STEM education strategy. *Science Education International*, *25*(1), 1–7.

Rizal, A., Ibnu Adam, R., & Susilawati, S. (2018). Pengembangan laboratorium virtual fisika osilasi. *Jurnal Online Informatika*, *3*(1), 55–60. https://doi.org/10.15575/JOIN.V3I1.140

Rohim, F. (2020). Need analysis of virtual laboratories for science education in Jambi, Indonesia. *Jurnal Sains Sosio Humaniora*, *4*(2), 744–755. https://doi.org/10.22437/jssh.v4i2.11539

Rokhim, D. A., Asrori, M. R., & Widarti, H. R. (2020). Pengembangan virtual laboratory pada praktikum pemisahan kimia terintegrasi telefon pintar. *JKTP: Jurnal Kajian Teknologi Pendidikan*, *3*(2), 216–226. https://doi.org/10.17977/UM038V3I22020P216

Sasmita, D., Adlim, M., Gani, A., & Syukri, M. (2021). Implementation of STEM-based student worksheet to increase student entrepreneurial innovation through the development of candied nutmeg products. *Jurnal Penelitian Pendidikan IPA*, *7*(1), 112–120. https://doi.org/10.29303/JPPIPA.V7I1.551

Smaldino, S. E., Lowther, D. L., & Russel, J. D. (2011). *Instructional technology and media for learning: teknologi pembelajaran dan media untuk belajar*. Kencana. https://lib.ui.ac.id

Syukri, M., Halim, L., Mohtar, L. E., & Soewarno, S. (2018). The impact of engineering design process in teaching and learning to enhance studentsâ€™ science problem-solving skills. *Jurnal Pendidikan IPA Indonesia*, *7*(1), 66–75. https://doi.org/10.15294/JPII.V7I1.12297

Thiagarajan, S., Semmel, D. S., & Semmel, M. E. (1974). *Instructional development for training teachers of exceptional children: A sourcebook*. ERIC.

Wahyuni, S. A., 'Ardhuha, J., Gunada, I. W., & Gunawan, G. (2022). Pengembangan perangkat pembelajaran fisika berbasis model problem based learning berbantuan simulai PhET untuk meningkatkan pemahaman konsep peserta didik. *Kappa Journal*, *6*(2), 220–229. https://doi.org/10.29408/KPJ.V6I2.6509

Wibowo. (2016). *Manajemen kinerja*. Rajawali Press.

Wibowo, F. C., Suhandi, A., Rusdiana, D., Samsudin, A., Darman, D. R., Faizin, M. N., Wiyanto, Supriyatman, Permanasari, A., Kaniawati, I., Setiawan, W., Karyanto, Y., Linuwih, S., Fatah, A., Subali, B., Hasani, A., & Hidayat, S. (2017). Effectiveness of dry cell microscopic simulation (DCMS) to promote conceptual understanding about battery. *Journal of Physics: Conference Series*, *877*(1), 1–10. https://doi.org/10.1088/1742-6596/877/1/012009