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Development of STEM-based Virtual Laboratory on Global Warming Topic for Junior High School Student

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Abstract: Our study aimed to develop a feasible STEM-based virtual laboratory on global warming topics for junior high school students. We used the development research type by adopting Thiagarajan's 4D model development procedure, which was limited to the development stage. The data collection methods we used were questionnaires and interviews, while the research instruments were interview sheets and questionnaires. Product validation involved a lecturer as a subject matter expert and a lecturer as a learning media expert. In addition, a small group evaluation sample with 10 students was selected using a simple random sampling technique to be involved in the product trial. Qualitative and quantitative data analysis techniques were used. The results showed that the assessment by subject matter experts received a feasibility percentage of 84%, including the criteria worth using, and the assessment by learning media experts received a feasibility percentage of 85%, including the criteria worth using. In addition, the small group student response trial showed 91%, which means the developed product is very practical. Thus, the STEM-based virtual laboratory on global warming topics was declared feasible for junior high school students to use in science learning.

Keywords: Global warming; Science education; STEM; Virtual laboratory

Introduction

The Covid-19 pandemic changes and forces various normal learning activities in schools to online learning situations as part of social distancing. Murphy (2020) stated that limiting face-to-face learning is the right action to support social distancing. This condition quickly led to digital transformation in education (Nikiforos, Tzanavaris, & Kermanidis, 2020). Bryson & Andres (2020) wrote that the Covid-19 pandemic forced teachers and students to quickly adjust to digital learning strategies without being limited by time and based at home. This moment became the first "digital pandemic" ever, where everyone stayed home, and the learning process became online.

In this post-pandemic period, in the modern era, online learning has become a new challenge as a result of the rapid changes in information technology (Wisanti, Ambawati, Putri, Rahayu, & Khaleyla, 2021; Wola, 2023). The effect of the rapid changes in society on education is that education must prepare generations to have certain skills needed by society (Taihuttu, Warouw, & Harahap, 2023). Kerres & Buchner (2022) stated that the world of education is faced with two options for continuing education after the pandemic. First, the idea of going back in time and bringing back the teaching and learning routines that existed before the pandemic. In this view, emergency remote teaching aided by digital tools is considered an exceptional case that will and can be abandoned when the need for remote education has ended. Secondly, the idea is that educational technologies developed during the pandemic are not only a temporary "emergency tool" to bridge the distance between teachers and students but a fast track to move the education system into the digital era. This perspective sees the future of education being linked to

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the digital environment to expand learning experiences through new approaches.

In science education, cognitive, affective and psychomotor learning outcomes can be maximally achieved when the learning process in the classroom can be integrated with practical activities in the laboratory. Laboratory experience plays an important role in providing experience in applying theories and concepts that students have learned to real situations (Triejunita, Putri, & Rosmansyah, 2021). In addition, laboratory experiments help students understand science lessons effectively (Wörner, Kuhn, & Scheiter, 2022). Laboratory activities can be an excellent way to develop mastery of science process skills (Wola, Rungkat, & Harindah, 2023). In this post-pandemic period, access to school laboratories should not only be limited to activities in physical (real) laboratories so that non-physical laboratories, such as virtual laboratories, can be an option to support learning.

Various limitations hamper access to real laboratories, making science learning less meaningful. Kapilan, Vidhya, & Gao (2021) reported that students need help understanding the content and instructions in conventional laboratory settings due to poor laboratory facilities and distractions from fellow students. In addition, the potential hazards of chemicals, the high cost of laboratory tools and materials, the obligation to use other laboratory tools or materials, and the use of lesson hours to (repeatedly) conduct traditional experiments are also limitations that need to be resolved (Kapici, Akcay, & de Jong, 2019). Therefore, learning innovations are needed to support laboratory activities when there are constraints and limited access to physical laboratories. Virtual laboratories can be proposed as an alternative solution (Triejunita, Putri, & Rosmansyah, 2021; Kapilan, Vidhya, & Gao, 2021; El Kharki, Berrada, & Burgos, 2021; Byukusenge, Nsanganwimana, & Tarmo, 2022).

Research on the development and use of virtual laboratories has increased in number in the last ten years. The National Science Foundation (NSF) in the United States proposed using virtual laboratory technology to enhance STEM learning to face global challenges in the 21st century (Borgman, Abelson, Dirks, Johnson, Koedinger, Linn, Lynch, Oblinger, Pea, & Salen, 2008). Abramov, Kugurakova, Rizvanov, Abramskiy, Manakhov, Evstafiev, & Ivanov (2017) stated that the virtual laboratory (v-lab, virtual reality laboratory) is a software that simulates the processes of real-life research laboratories with experiments and research practice. We define a virtual laboratory as imitating a real laboratory that can simulate practical activities through computers, mobile devices, and internet-assisted electronic tablets. Virtual laboratories can be a practical learning resource because they can be accessed anywhere and anytime through the internet. Jaya, Lumu, Haryoko, & Suhaeb (2020) stated that virtual laboratories are needed to strengthen concept understanding in learning.

Various virtual laboratories have been successfully developed by previous researchers in science subjects in junior high schools (Purwanti, Habibah, & Supriyanto, 2014; Nurhayati & Rohman, 2015; Ismail, Permanasari, & Setiawan, 2016; Adita & Julianto, 2016; Widowati, Nurohman, & Setyowarno, 2017; Sholikhah, Widowati, & Wibowo, 2017; Utami, Widowati, & Wibowo, 2017; Sabrinah, Tulenan, & Sompie, 2021; Herunata, Fadilah, & Affriyenni, 2022; Syukri, Rahmi, Saminan, Subramaniam, Artika, Huda, & Khaldun, 2022; Noris, Saputro, & Muzazzinah, 2022; Rahmi, Saminan, Syukri, Yusrizal, Khaldun, Artika, & Huda, 2022; Revanza, Ridlo, & Rizqi, 2023). However, only some STEM-based virtual laboratories on global warming topics for junior high school students have been reported. Utami, Widowati, & Wibowo (2017) developed a virtual laboratory on global warming topics but needed to provide information about the electronic media used to access the virtual laboratory developed. In addition, the virtual laboratory was not developed based on the STEM approach.

STEM is a learning approach that can improve the quality of education in the 21st century (Mamahit, Aloysius, & Suwono, 2020; Mardita, Alim, Hermita, & Wijaya, 2022; Mercan, Papadakis, Can Gözüm, & Kalogiannakis, 2022; Rungkat, Jeujanan, & Wola, 2023). Rusydiyah, Indarwati, Jazil, Susilawati, & Gusniwati (2021) define the STEM approach as a learning approach that encourages students to deal with complex contexts using knowledge and skills from various disciplines in the STEM field. The STEM approach in science learning features a connection between scientific inquiry activities with the ability to formulate research questions through scientific inquiry and engage in the engineering design process to solve problems (Rosana, Kadarisman, Purwanto, & Sari, 2021). Resource availability is one determinant of effective STEM-based learning (Cheng & So, 2020; Pondoki, Warouw, & Rungkat, 2023).

Based on the results of the researcher's observations at SMP Negeri 23 North Halmahera in March 2022, we found interesting facts that the school provides electronic tablet facilities to all students for online learning and has a smooth WiFi network. However, we also found some problems, specifically: (1) teachers are not familiar with the virtual laboratory; (2) science learning has never used the virtual laboratory; (3) virtual science laboratory is not yet available; (4) laboratory facilities and infrastructure are not yet available; (5) there are no practicum activities on the topic of global warming. Therefore, it is important to present learning innovations in the form of a virtual laboratory. Our research objectives are to develop a feasible STEM-based virtual laboratory on global warming topics for junior high school students. We chose this topic because the subject content covers events in the atmosphere that are very broad and involve greenhouse gases, so they are abstract. Ultimately, the STEM-based virtual laboratory we developed provides simulated experiments on abstract science content to complement theoretical understanding and present more meaningful learning.

Method

This research was conducted from March to June 2022. From March to May 2022, the product development stage was carried out at the Department of Science Education, Universitas Negeri Manado. Student response test in small group evaluation at SMP Negeri 23 North Halmahera was conducted in June 2022. We used development research type by adopting the 4D model development procedure by Thiagarajan, Semmel, & Semmel (1974). The define stage is the initial stage to obtain initial information about the problems and urgency underlying the need to develop learning innovation products. The design stage is the stage of designing the type of product to be developed based on the needs analysis results in the previous stage. The development stage translates the product design into a real product, followed by assessment and improvement. Assessment of product feasibility was carried out by one subject matter expert lecturer and one expert media lecturer. In contrast, ten students carried practicality information through small group evaluation. In this study, product development was limited to the development stage and did not proceed to the dissemination stage with consideration of time and funds.

The questionnaire technique was used to collect data about the feasibility and practicality of the developed product. In contrast, the interview technique collected information about potential problems, criticisms, suggestions, and responses from subject matter and learning media experts. The research instruments were in the form of interview sheets and questionnaires. The questionnaire consisted of a subject matter expert validation questionnaire, a media expert validation questionnaire, and a student response questionnaire. Qualitative and quantitative data analysis techniques were used. Qualitative data analysis to find information on the urgency of development research, criticism, and suggestions during the product development stage. Quantitative data analysis to analyze the assessment score on the expert validation questionnaire and student response questionnaire. The calculation of the average questionnaire score uses a Likert scale consisting of five categories, as seen in Table 1.

Table 1. Scoring Categories

Score		Category
5	Very valid	Strongly agree
4	Valid	Agree
3	Quite valid	Quite agree
2	Less valid	Less agree
1	Invalid	Disagree

(Arikunto, 2010)

The scores obtained were then analyzed using the method of summated ratings (MSR) to get the percentage of validity with Equation 1:

$$P = \frac{\sum R}{N} \times 100\% \quad (1)$$

P represents the validity percentage, $\sum R$ represents the total score by validators or students, and N represents the maximum score. The percentage figures obtained are then interpreted into the product feasibility and practicality criteria, which can be seen in Table 2.

Table 2. Percentage of Product Feasibility and Practicality Assessment Criteria

Percentage of Criteria Achievement Level	Criteria	
	Feasibility	Practicality
86% - 100%	Very feasible; no need to revise.	Very practical
61% - 85%	Feasible, needs minor revision.	Practical
41% - 60%	Quite feasible, needs moderate revision.	Quite practical
21% - 40%	Less feasible, needs major revision.	Less practical
≤ 20%	Not feasible, cannot be used.	Not practical

Based on Table 2, the STEM-based virtual laboratory is declared feasible to use if it meets a minimum percentage of ≥ 61%.

Result and Discussion

The explanation of the STEM-based virtual laboratory product development results on global warming topics is based on the 4D development model, which is limited to the development stage.

Define

Researchers conducted front-end, curriculum, student/learner, and concept analyses at this stage. The front-end analysis found that science teachers were unfamiliar with the virtual laboratory and had never used it. There was no virtual science laboratory available, and there were no practicum activities on global warming topics. In addition, the school does not have a science laboratory, so the science practicum has been done with simple tools and materials. The curriculum analysis shows that SMP Negeri 23 North Halmahera uses the 2013 Curriculum, and identification of the basic competencies (KD) of knowledge and skills is also carried out. The topic of global warming is taught to seventh-grade students. Furthermore, it is known that the knowledge KD is analyzing climate change and its impact on ecosystems, while the skill KD is writing about ideas for adaptation / overcoming climate change problems. At the student/learner analysis stage, it was known that students' learning outcomes on global warming topics were still classified as intermediate, students had never done a practicum on global warming, and students were used to using smartphones. At the concept analysis stage, the researcher identified the concepts on the topic of global warming studied and their depth.

Design

To facilitate the development process of developing a STEM-based virtual laboratory at the development stage, a flowchart, storyboard, and user interface design were made at this design stage. The flowchart model chosen is the model for the simulation program, which can be seen in Figure 1. The storyboard describes the learning flow that contains virtual laboratory information, procedures, and instructions for using the STEM-based virtual laboratory. In general, this STEM-based virtual laboratory's components on global warming topics include developer profile identity, login menu, instructions for use, learning competencies, learning content, experiments on modeling the greenhouse effect, experiments on modeling ozone layer depletion, and learning evaluation. The user interface is designed to provide convenience to users (see Table 3). The sub-topics of global warming in the developed STEM-based virtual laboratory are the greenhouse effect, ozone layer, global warming and causes, and how to overcome global warming.

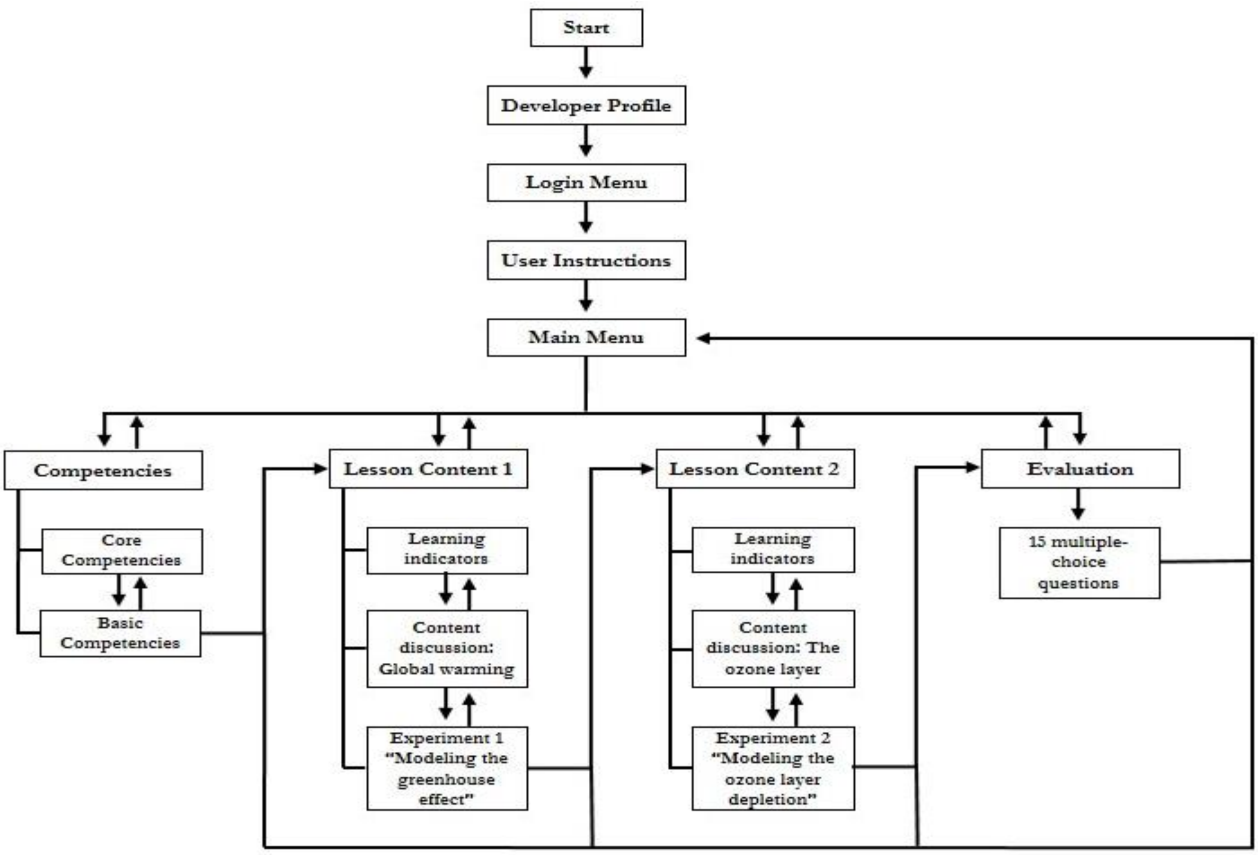


Figure 1. Flowchart of STEM-based virtual laboratory on global warming topic

Based on Figure 1, it can be seen that the virtual laboratory starts with the start menu. Once clicked, the user will see an opening display about the developer's profile. Then students are required to fill in the name and class as a user database that will be displayed on the printout of the evaluation answers. The next display is instructions for using a STEM-based virtual laboratory that provides a description of use to make it easier for students to use a STEM-based virtual laboratory. Furthermore, the main menu display consists of competencies, subject matter 1 and 2, and evaluation.

Table 3. User Interface of STEM-based Virtual Laboratory on Global Warming Topic

Navigation Buttons	Description
MULAI	Experiment start button
OK, LANJUT!	Approval button to go to the next page
OK	Approval button to go to the next page
	Button to go to the homepage or main page
	Button to go to the previous page
	Button to go to the next page
Baca	Button to read the subject matter
Cetak	Button to print answer results
	Button to send answer results to email

Experimental activities will be presented every time student finish learning the subject matter. The first experiment models the greenhouse effect, while the second models the ozone layer depletion. At the end of the learning activity, students are presented with an evaluation consisting of 15 multiple-choice questions. At the end of the test, students can print the evaluation results and share the results via email.

Development

The storyboard that has been made at the design stage is then translated into the form of a STEM-based virtual laboratory. The components contained in the virtual laboratory are adjusted to the description contained in the storyboard. We produced a STEM-based virtual laboratory using Articulate Storyline application software. The display of the STEM-based virtual laboratory production process using Articulate Storyline can be seen in Figure 2.

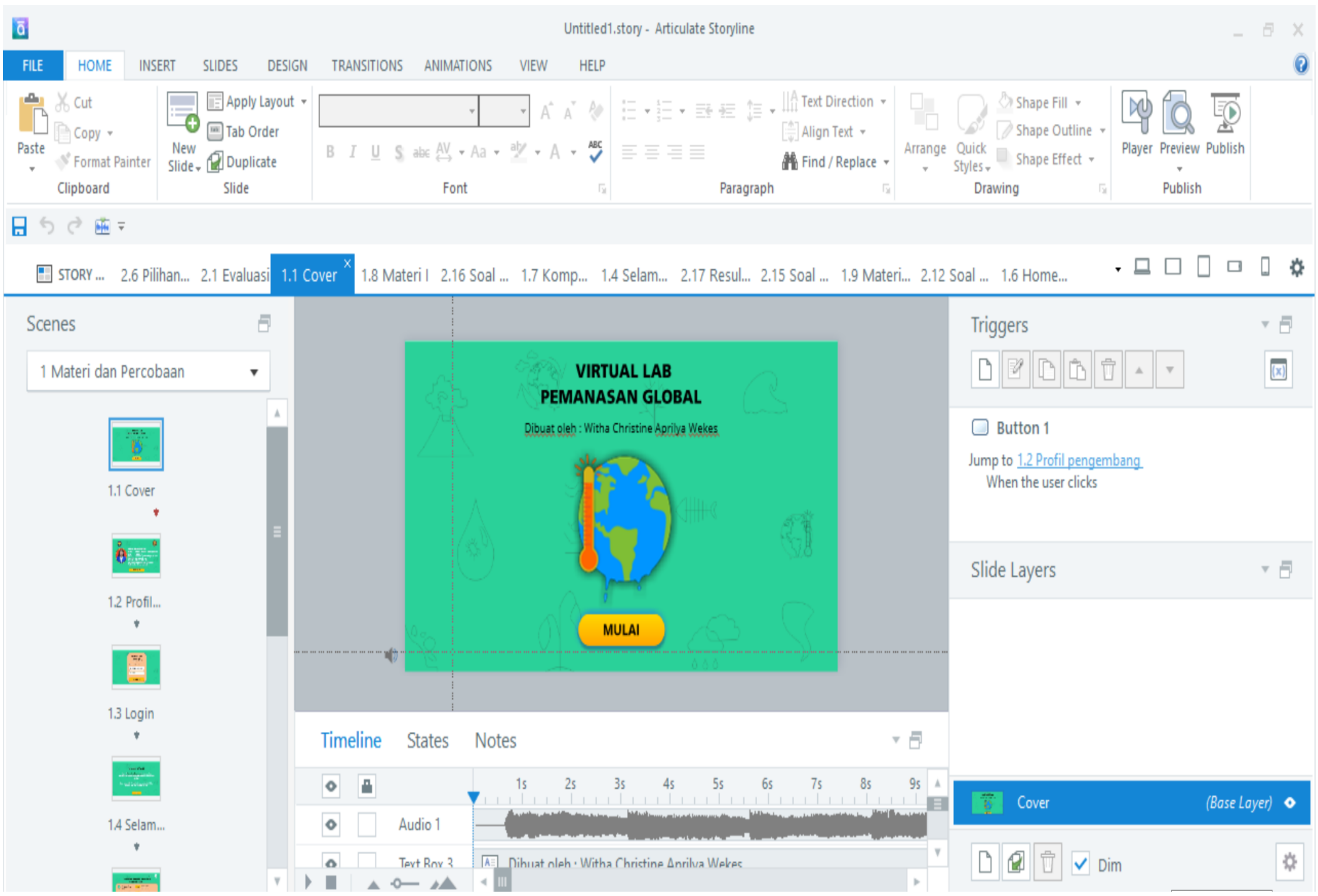


Figure 2. Display of the STEM-based virtual laboratory production process using an Articulate Storyline

After the STEM-based virtual laboratory was produced (draft 1), it was assessed for feasibility by validators consisting of lecturers who are experts in subject matter and learning media. The validation results and suggestions for improvement by validators were used to revise the STEM-based virtual laboratory. The results of the subject matter expert validation are shown in Table 4.

Table 4. Subject Matter Expert Validation Results

Aspects	Component	Indicator	Score
Content	Curriculum	1. Suitability with core and basic competencies	5
		2. Suitability of indicators with core and basic competences	5
		3. Suitability of subject matter with the scope of science in grade seven	5
	User	4. Suitability of the way of delivering material with student development	5
		5. Providing opportunities for self-learning	5
		6. Demands student activity	5
		7. Pay attention to individual differences	4
Learning	Opening	8. The attractiveness of the title	5
		9. Appropriateness of apperception to learning objectives and content	5
	Core	10. The orderliness of subject matter presentation	4
		11. The truth of the subject matter	4
		12. Clarity of subject matter	4
		13. STEM content in the subject matter	4
		14. Depth of subject matter	4
		15. The attractiveness of content presentation	5
		16. Suitability of the discussion with refined spelling (EYD)	3
		17. Language suitability to the user's level of understanding	3
		18. Suitability of quiz questions with indicators	3
	Closure	19. Systematics of quiz questions	3
		20. Quality of feedback	3
Total			84
Percentage (%)			84%

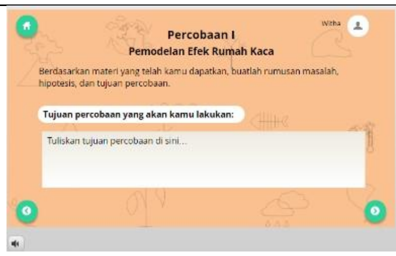
Based on the subject matter expert validation results, it is known that the STEM-based virtual laboratory developed obtained a percentage of 84%, including the criteria worth using with minor revisions. In addition, the subject matter expert validator also provided comments in the form of criticism and suggestions, namely add a description of the virtual laboratory developer's profile, add a reference source of subject matter (references), display the purpose of the experiment, add questions about the topic of global warming to the quiz, add subject matter referenced from science textbooks, and images as instructions are made unified and synchronous. Furthermore, the results of learning media expert validation can be seen in Table 5.

Table 5. Learning Media Expert Validation Results

Aspect	Component	Indicator	Score
Appearance	Layout design	1. Appropriateness of background selection with subject matter	4
		2. Accuracy of color proportion with the layout	3
	Text/Typography	3. Appropriateness of font selection for easy reading	4
		4. Appropriateness of font size for easy reading	4
		5. Text color accuracy for easy reading	4
	Picture	6. Picture composition	5
		7. Size picture	5
		8. Picture display quality	4
	Animation	9. Suitability of animation with subject matter	4
		10. Animation attractiveness	5
		11. Accuracy of sound effects with animation	3
	Packaging	12. Cover attractiveness	3
		13. Appropriateness of appearance with content	4
Programming	Use	14. Conformance to the user	5
		15. Usability (easy to use, simpleto operate)	4
		16. Flexibility (can be used independently and guided)	5
		17. Completeness of instructions for use	5
		18. Display of instructions for use	5
		19. Presents benchmarks for learning success	5
	Navigation	20. Accuracy of navigation button usage	4
		Total	85
		Percentage (%)	85%

Based on the results of the learning media expert validation, it is known that the STEM-based virtual laboratory developed obtained a percentage of 85%, including the criteria worth using with minor revisions. In addition, learning media expert validators also provided comments in the form of criticism and suggestions that the media developed must be used in a stable internet situation and still be under the teacher's guidance. Researchers have improved the STEM-based virtual laboratory based on the criticisms and suggestions of subject matter and learning media expert validators. The media display before and after revision can be seen in Table 6.

Table 6. Corrections to STEM-Based Virtual Laboratory

Part	Before	After
Developer profile	None	
Subject matter I		
Experiment I		
Experiment I		
Subject matter II		

Part	Before	After
References	None	
Evaluation		

After the product was declared feasible, it was tested on a small group of 10 students to assess the practicality of the STEM-based virtual laboratory. The results of the small group assessment are shown in Table 7.

Table 7. Small Group Trial Results

No.	Statements	Student Code										Average	%	Criteria
		1	2	3	4	5	6	7	8	9	10			
1	I am interested in participating in practicum on global warming material using STEM-based virtual laboratory	5	5	4	5	4	5	5	5	5	5	4,8	96	Very practical
2	STEM-based virtual laboratory that I use is in accordance with the learning objectives	4	4	5	4	5	4	4	5	4	4	4,3	86	Very practical
3	STEM-based virtual laboratory is easy to operate	5	4	4	5	4	4	4	4	4	5	4,3	86	Very practical
4	STEM-based virtual laboratory that I use helps me understand the subject matter on global warming	5	4	5	5	5	5	5	5	4	5	4,8	96	Very practical
5	The display of pictures and animations in this STEM-based virtual laboratory is interesting	4	4	4	4	4	5	4	5	5	4	4,3	86	Very practical
6	I am happy to be given the opportunity to do practice questions and get new information	4	5	4	5	5	4	5	4	5	5	4,6	92	Very practical
7	I am more motivated to do experiments using a STEM-based virtual laboratory	4	4	5	5	4	5	5	5	4	5	4,6	92	Very practical
8	I can play animations in this STEM-based virtual laboratory independently	5	5	4	4	5	4	5	4	4	5	4,5	90	Very practical
9	I think practicum through a STEM-based virtual laboratory is more effective and efficient	4	5	4	5	4	5	5	4	5	4	4,5	90	Very practical
10	I am interested if practicum activities are carried out in a STEM-based virtual laboratory on other topics	5	5	4	5	5	4	4	4	5	5	4,6	92	Very practical
													91	Very practical

Table 7 shows that the results of the STEM-based virtual laboratory trials in small groups obtained a value of 91%. Thus, the developed STEM-based virtual laboratory is stated to be very practical for use by junior high school students.

This research has successfully developed a learning innovation product in the form of a STEM-based virtual laboratory on global warming topic that is suitable for use by junior high school students. In general, this product was developed to overcome the limitations of science learning in junior high school on global warming. The topic is abstract for students because the subject matter discussed includes events in the atmosphere that are very broad and involve greenhouse gases that cannot be observed directly. The virtual laboratory we developed can simulate these abstract experiments to complement the understanding of the theory and present more meaningful learning for students. Our STEM-based virtual laboratory can be accessed at https://tinyurl.com/29s79e6z. Our virtual laboratory can be accessed by science teachers and students in science classes through smartphones, electronic tablets, and computers via the internet. It aligns with school conditions, where each student is given an electronic tablet facility and has a smooth WiFi network.

The virtual laboratory we developed (draft 1) was tested for feasibility through subject matter and learning media experts' validation activities. The validation results by subject matter experts showed a feasibility percentage of 84%, including the criteria for feasible use with minor revisions. The virtual laboratory that has been improved based on the criticisms and suggestions of subject matter experts is called draft 2, then validated by learning media experts. The validation results by learning media experts showed a feasibility percentage of 85% and were included in the criteria worth using with minor revisions. Once again, the virtual laboratory was improved based on criticism and suggestions by learning media experts. Based on the assessment of subject matter and learning media experts, the STEM-based virtual laboratory on the topic of global warming is declared suitable for use. This finding is in line with research by Ismail, Permanasari, & Setiawan (2016) reported that the STEM-based virtual lab they developed on water pollution topic was very feasible to use based on the validation of learning media experts with 86% feasibility.

Utilizing a virtual laboratory as an innovative learning tool can improve student understanding, develop competencies through practical experience, and improve learning outcomes (Estriegana, Medina-Merodio, & Barchino, 2019). However, such expectations are meaningless if students are not interested in using the product. Therefore, while still placing students at the center of the teaching and learning process, we also wanted to know the practicality of use reported by students when using this virtual laboratory through a user response questionnaire (students). The improved virtual laboratory (draft 3) was then tested on a small group of 10 junior high school students to obtain information about the product's practicality. The trial results showed a practicality percentage of 91%, so the STEM-based virtual laboratory on global warming topic was declared very practical to use. This finding aligns with research by Hidayat & Utomo (2015), who reported that the virtual laboratory they developed received 93%, so it was very practical. Rahmi et al. (2022) also reported that the virtual lab in science-physics learning based on the STEM approach they developed was very practical based on acquiring a 96% practicality percentage in the student response trial.

Using virtual laboratories in practicum can visualize abstract concepts to be more concrete so that students are challenged to analyze, criticize, and make conclusions about the concepts learned (Kapilan Kapilan, Vidhya, & Gao, 2021). Virtual environments allow newer possibilities for conducting simulations and experiments that are sometimes impossible in physical laboratories (Alkhaldi et al., 2016). Potkonjak, Gardner, Callaghan, Mattila, Guetl, Petrović, & Jovanović (2016) suggested the advantages and disadvantages of virtual laboratories. The advantages of virtual laboratories, namely saving operational costs, flexibility regarding tools and materials, can be accessed by many students simultaneously, it is possibility to modify parameters that often cannot be changed in a real system, damage resistance, and making the "unseen thing" seen. As for the shortcomings of the virtual laboratory, namely requiring access through electronic devices (computers), the unreal nature of a virtual system can lead to a less serious and thorough attitude of students and does not provide real hands-on experience. Zacharia & de Jong (2014) stated that the experience of using a virtual laboratory first could help students be skilled to work in a real laboratory later on.

Our virtual laboratory product is learning innovation that helps science teachers present science learning with STEM content for junior high school students. It contributes to today's science learning in junior high school as a STEM learning resource. Firman, Rustaman, & Suwarma (2015) stated that STEM-based science learning is a form of STEM education in accordance with the 2013 curriculum system that applies in Indonesia. One effective integration of STEM-based learning depends on the availability of resources to access subject matter. The STEM-based virtual laboratory on global warming topic that we have developed can bring students to study science content, use technology (gadgets and the internet), design experimental tools, and perform mathematical calculations. STEM learning steps integrated into a virtual laboratory provide opportunities for students to think critically through problem-solving, decision-making, analyzing assumptions, evaluating and conducting investigations and creating new experiences. Baharin, Kamarudin, & Manaf (2018) stated that STEM learning could provide meaningful learning experiences for students in 21st-century learning by integrating scientific literacy, knowledge, the use of technology, and mathematical literacy. Various previous studies have reported that STEM-based virtual laboratories are effective in increasing students' scientific literacy (Ismail, Permanasari, & Setiawan, 2016), problem-solving skills (Laila & Anggaryani, 2021), critical thinking skills (Trisnaningsih, Parno, & Setiawan, 2021; Sari, Angreni, & Salsa, 2022), learning outcomes (Syukri et al., 2022), and student creativity (Rahmadani, Ariani, Mulyani, & Indriyanti, 2023). Ismail, Permanasari, & Setiawan (2016) stated that integrating several disciplines into one subject so that it becomes comprehensive can help students gain knowledge of science concepts and implement them in everyday life.

Conclusion

Based on the research that has been done, it is proven that STEM-based virtual laboratories on global warming topics are appropriate for junior high school students to use. It is supported by data from the assessment results by subject matter experts with an eligibility percentage of 84% included in the criteria for appropriate use and an assessment by learning media experts with an eligibility percentage of 85% included in the appropriate criteria for use. In addition, student response trials in small groups showed a score of 91%, which means that the product being developed is very practical to use. Our recommendation for future research is the assessment of the product's effectiveness on a broader sample and how it supports various 21st-century skills in science learning.

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Author Contributions

Conceptualization, Z.W.M.W., W.C.A.W., and F.H.; methodology Z.W.M.W., W.C.A.W., and F.H.; software, W.C.A.W.; validation, Z.W.M.W. and W.A.T.; formal analysis, Z.W.M.W. and B.R.W.; investigation, Z.W.M.W. and W.C.A.W.; resources, Z.W.M.W.; data curation, W.C.A.W.; writing—original draft preparation, Z.W.M.W. and W.C.A.W.; writing—review and editing, W.A.T. and B.R.W.; visualization, W.C.A.W. and F.H.; supervision, Z.W.M.W. and F.H.; project administration, Z.W.M.W.; funding acquisition, Z.W.M.W., W.C.A.W., F.H., and W.A.T. All authors have read and agreed to the published version of the manuscript.

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Conflicts of Interest

The authors declare no conflict of interest.

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