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Reinventing the Physics Lab: Designing an Effective Science Process-Based Virtual

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Abstract:

The limited physics practicum activities in schools, caused by equipment damage and lack of technology utilization, prompted the birth of a virtual laboratory innovation called *Kymatica Lab*. This innovation was developed as a learning medium based on science process skills. The main purpose of this study is to design and test the extent to which *Kymatica Lab* is feasible and practical to use in the learning process. This research uses a *Research and Development* (R&D) approach with the ADDIE model, which includes the stages of Analysis, Design, Development, Implementation, and Evaluation. Product testing is carried out in a quantitative descriptive manner to assess the feasibility and practicality aspects of this virtual laboratory. The validation results from experts in the fields of media, materials, learning, and evaluation show that *Kymatica Lab* is very worth using. In addition, after being tested on students, this virtual laboratory is also considered very practical based on the implementation of learning, science process skill questionnaires, and students' responses to the use of these media.

Keywords: Science Process Skills; Virtual Laboratory; Research and Development

Introduction

Natural Sciences (IPA) is one of the main components in the school's educational curriculum. Currently, Indonesia implements the Independent Curriculum as the basis of the learning process. At the junior high school level, especially grades VII to IX, the main focus of learning activities is directed at developing students' competencies through contextual approaches that are relevant to daily life (Wahyudin et al., 2024). In science education at this level, there are two essential elements, namely science understanding and science process skills. The understanding of science aims to provide a deep mastery of the basic theories and principles of the branches of natural sciences, such as physics, chemistry, biology, and earth and space sciences. Meanwhile, science process skills are focused on developing students' practical abilities in observing, measuring, analyzing data, and testing hypotheses, which will indirectly form a critical mindset and the ability to conduct research systematically (Kemendikbudristek, 2022). Among the three branches of science at the junior high school level, physics often faces various challenges that can hinder students' understanding. These challenges were also felt by Subject Teachers (GMP) in one of the schools in the Kediri area.

Based on the results of interviews with science teachers at the school, the majority of students' difficulties lie in materials related to vibration, waves, and light. In addition, it was also found that practicum equipment in laboratories has not fully functioned post-pandemic, so some practicum tools are not available or have been damaged. This condition causes practicum activities to not be carried out optimally. The practicum carried out at this time is limited to simple activities with materials from home and tools that are still functioning, so that students' practical skills in conducting experiments are still relatively lacking. As a result, the process of understanding physics concepts that require direct practical activities is hampered.

In general, the purpose of practicum activities in the laboratory is to increase students' interest in science learning through demonstrations and hands-on experiments. Students tend to remember the material better if the learning process is not only theoretical. Learning activities that do not involve students actively participating can make learning less meaningful (Yusal et al., 2023). Learning through demonstrations and practicums allows students to not only listen but also see and perform in person. Experts agree that learning that involves visual and self-directed experiences can have a significant impact on concept understanding (Mardhatilla, 2021). More than that, practicum activities also play a role in developing science process skills (Utami & Aryani, 2024). Where practicum activities have a positive and significant impact on science process skills. The practicum accustomed students to follow systematic steps, make observations, and analyze data, so that they can develop their science process skills (Satriani & Hardiyanti, 2020).

These science process skills are very important because they not only support the understanding of scientific concepts, but also help students in developing critical, creative, and analytical thinking skills. According to guidelines from the Ministry of Education and Culture, there are six main indicators in science process skills that students must master, namely: observing, asking questions and predicting, processing and analyzing data, conducting evaluations and reflections, and communicating results

(Kemendikbudristek, 2022). With the mastery of these skills, students will be more competent in solving problems, conducting research, and applying science knowledge in daily life.

In a previous interview, the science teacher stated that the physics material has a fairly high level of difficulty, especially because of the formulas and calculation skills that must be mastered. This encourages teachers to continue to innovate in developing interesting and easy-to-understand learning methods and media. One solution that can be used is the use of technology such as virtual laboratories, which has the potential to improve the process of learning physics, especially for materials that are difficult to understand (Maiyanti et al., 2024). However, at the junior high school level, the use of information technology in teaching and learning activities is still not optimal. Teachers tend to rely on textbooks and whiteboards without more interactive technology optimization (Arnaz et al., 2022).

In one of the schools in the Kediri area, science learning still relies on LKS books as the main learning medium. Based on the results of the interview, the science teacher at the school only used projectors to show animated videos from YouTube. The use of more sophisticated and interactive technology has not been fully integrated into the learning process, so students' learning experiences are still limited. In fact, computer laboratory facilities and internet connections are available, so this technology should be used optimally so that the learning experience becomes more interesting and meaningful. A learning approach that integrates hands-on practice with technology is expected to help students not only understand theory, but also be able to see its application in real-world situations. One of the uses of technology that can be used is an android-based application as a learning medium (Saidah et al., 2022).

The development of virtual laboratories can be an effective solution to overcome these problems. Several studies have shown that there is a significant improvement in science process skills by utilizing virtual laboratories. For example, research by Istiqomah on high school students showed an increase in process skills scores after participating in a virtual-based practicum (Istiqomah, 2020). In addition, research by Arumningtyas et al. also supports these findings, especially on the material on Archimedes' Law (Arumningtyas et al., 2022). Lastly, research conducted by Ratnasari et al. showed a significant influence on the understanding of concepts and skills by using learning media in the form of virtual physics laboratories (Ratnasari et al., 2023).

Based on this background, the researcher plans to develop an Android application in the form of a virtual laboratory called Kymatica Lab which aims to be a supporting medium in the learning process at school. This development aims to assess the development, feasibility, and practicality of using Kymatica Lab, especially in vibration, wave, and light materials with an approach to science process skills of grade VIII students at MTs Sunan Gunung Jati.

Methods

In this study, the researcher used research and development methods (*Research & Development/R&D*) by applying the ADDIE model. According to Sugiyono, *Research & Development* is a method applied in order to develop or produce a certain product by testing its effectiveness (Scott, 2013). The stages in the ADDIE model include five main steps, namely: *Analysis* (Analysis), *Design* (Planning), *Development* (Development), *Implementation* (Implementation), and *Evaluation* (Evaluation) (Waruwu, 2024). Figure 1 shows the following stages in the ADDIE model:

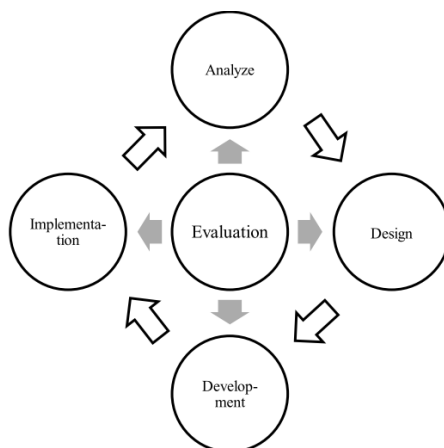


Figure 1. ADDIE Model Stages
(Source: Waruwu, 2024)

Kymatica Lab's trial uses a quantitative descriptive research design to determine the feasibility and practicality of the product. Quantitative descriptive research aims to describe and analyze numerical data objectively, without testing specific hypotheses (Sari & Suprajang, 2020). This research and development will take place from December 6, 2024 to June 11, 2025. The subjects of the Kymatica Lab virtual laboratory product trial involved various parties, including media experts, material experts, learning experts, learning evaluation experts, and 32 grade VIII A students at one of the schools in the Kediri area as product users.

The data collection instrument consists of validation questionnaires from experts (media experts, material experts, learning experts, and learning evaluation experts) to assess the feasibility of Kymatica Lab's virtual laboratory and its supporting devices as learning media. Furthermore, science process skills questionnaires, student response questionnaires, student science process skills observation sheets, and learning implementation sheets were used to find out the practicality of Kymatica Lab as a learning medium. In addition to the quantitative data, this study also collects qualitative data through interviews, direct field observations, documentation from activities in schools, and comments from validators. The data analysis techniques in this study include:

1. Test the validity of the questionnaire item with the following Aiken's V formula (Nabil et al., 2022):

$$V = \frac{\sum s}{n(c - 1)}$$

(Source: Nabil et al., 2022)

Description:

Σs : Total score by experts
 n : Number of members
 c : Highest score (4)
 1 : lowest score

The validation values obtained will be interpreted based on the categories defined in table 1 below (Febriandi et al., 2019):

Table 1. Aiken's V Validation Categories

No.	Correlation Coefficients	Validation Categories
1.	>0.80	Very High
2.	$0.60 < V < 0.80$	Height
3.	$0.40 < V < 0.60$	Enough
4.	$0 < V < 0.40$	Low

(Source: Febriandi et al., 2019)

- The reliability test of the questionnaire items is carried out by calculation *Cronbach's Alpha* using IBM SPSS Statistics 2022 software. If the value *Cronbach's Alpha* > 0.60, then the questionnaire is categorized as reliable (Anggraini et al., 2022).
- The feasibility analysis of learning media was obtained through the results of questionnaires from experts (media, materials, learning, and learning evaluation). The questionnaire was filled out using a Likert scale with a score between 1 to 4. The percentage of media eligibility from validators is calculated by the formula:

$$P(\%) = \frac{\Sigma \text{ skor dari validator}}{\Sigma \text{ skor maksimum}} \times 100\%$$

The interpretation of the results of the analysis is based on the categories listed in table 2 below. (Muhsan et al., 2022):

Table 2. Learning Media Qualification Category

Clasification	Percentage
Very less feasible	0% - 20%
Less worthy	21% - 40%
Quite feasible	41% - 60%
Worthy	61% - 80%
Highly feasible	81% - 100%

(Source: Arikunto in Muhsan et al., 2022)

- Analysis of the practicality of learning media was obtained from learning implementation sheets, student science process skills questionnaires, and student

response questionnaires to the use of these media. The analysis technique is carried out with the following formula (Annisa et al., 2020):

$$P(\%) = \frac{\Sigma \text{ skor dari responden}}{\Sigma \text{ skor maksimum}} \times 100\%$$

The interpretation of the level of practicality refers to the following table 3:

Table 3. Categories of Learning Media Practicality

Klasifikasi	Percentage
Very impractical	0% - 20%
Less practical	21% - 40%
Quite practical	41% - 60%
Practical	61% - 80%
Very practical	81% - 100%

(Source: Annisa et al., 2022)

Results

Kymatica Lab Development Procedure

Analysis Stage

1) Student Needs Analysis

The results of interviews with science teachers at one of the schools in the Kediri area show that physics material is the main difficulty for students, so they need extra assistance to understand the material. In addition, the limitations of practicum facilities, the lack of student skills in conducting practicums, and the lack of use of technology-based learning media are obstacles in the implementation of science learning, especially materials that require direct practice. To overcome these problems, researchers developed learning media in the form of Kymatica Lab virtual laboratories designed for vibration, wave, and light materials.

2) Curriculum Analysis

The curriculum used in science learning in one of the schools in the Kediri area is the Independent Curriculum, with learning outcomes and learning objectives in accordance with the elements of science process skills as shown in table 4 below:

Table 4. CP and TP Vibration, Wave, and Light Materials

Elements	Learning Outcomes	Learning Objectives
Science Process Skills	Observing	Students can use a variety of tools to make measurements and observations of vibration, wave, and light phenomena, as well as pay attention to the relevant details of the observed objects.
	Questioning and predicting	Students can ask questions to clarify the results of observations

	and make predictions about vibration, wave, and light events in a variety of situations.
Plan and conduct investigations	Students can plan and execute practicums to investigate the properties of vibration, waves, and light.
Processing, analyzing data and information	Students can present observational data in the form of tables, graphs, or models, as well as analyze patterns or relationships that emerge from the data.
Evaluating and reflection	Students can evaluate the conclusions drawn from investigations by comparing them with existing theories.
Communicate results	Students can communicate the results of investigations about vibration, waves, and light by using logical arguments and appropriate science language, as well as following a prescribed format.

(Source: <https://guru.kemdikbud.go.id/>)

Design Stage

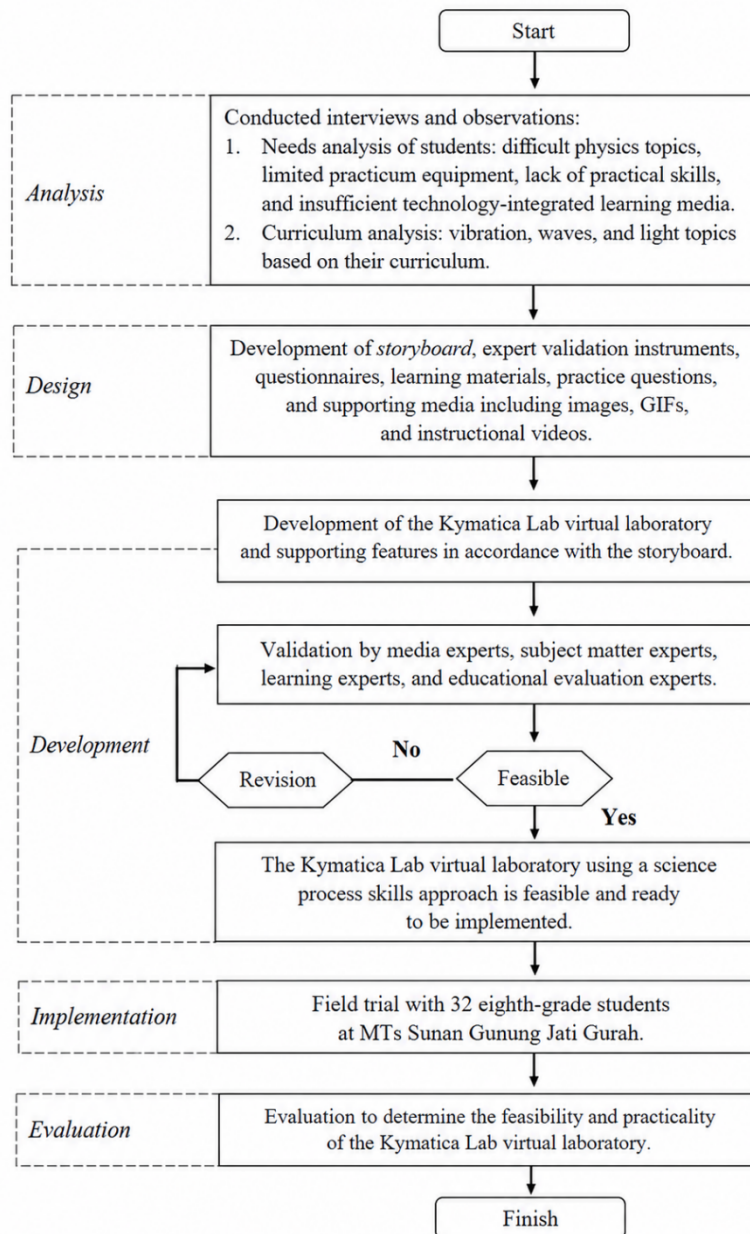
In this stage, the researcher collected various learning materials related to vibration, waves, and light from relevant sources as the basic materials for the development of modules and practicum tools in the Kymatica Lab virtual laboratory. Furthermore, the researcher compiled practice questions in the form of quizzes to measure students' understanding of the material. This stage also includes the creation of *storyboards* as media designs, validation instruments, student science process skills questionnaires, student response questionnaires, and science process skills observation sheets.

Development Stage

The development of Kymatica Lab was carried out according to the storyboard that had been prepared. After the product is completed, a validation process is carried out to ensure that the virtual laboratory meets the necessary quality standards so that the product is considered suitable as a learning medium.

1) Kymatica Lab's Development Results

Figure 2 below shows the development flow of the Kymatica lab virtual laboratory. The final results of the Kymatica Lab application can be downloaded via [the https://bit.ly/45Isirm](https://bit.ly/45Isirm) link.



(Source: Researcher documentation)

Figure 2. Kymatica Lab Development Flowchart

Implementation Stage

The Kymatica Lab virtual laboratory, which has been validated by experts, is then applied as a learning medium in grade VIII A. Cooperation is carried out with science teachers as observers and facilitators in ensuring the success of the teaching and learning process. Learning takes place over four meeting sessions where students are divided into six study groups, each using a mobile phone to access Kymatica Lab as per the guidelines provided. At the first meeting, students conducted a practicum related to the frequency and period of vibration. Then at the second meeting, students did a practicum related to the frequency of periods, and the speed of wave propagation. In the third meeting, students conducted a practicum related to the properties of light, and in the fourth meeting, they reviewed and reflected on the

practicum activities that had been carried out. In addition, they also filled out a science process skills questionnaire and a student response questionnaire. The researcher's observation of students' science process skills during the practicum of meetings 1, 2, and 3 was recorded on the observation sheet.

The students' science process skills get a total percentage of 88.85%. Based on the practicality criteria in table 3, this number is included in the category of very practical, so this virtual laboratory is very practical to use as a learning medium. In addition, the improvement of students' science process skills at each meeting also shows the practicality of this medium. This data was obtained through direct observation by the researcher during the practicum and filled it in on the observation sheet.

The improvement of science process skills can be seen from various aspects, such as at the beginning of the implementation, the observing aspect of some students was still relatively low compared to the second and third meetings. At first, some students had difficulty operating virtual labs, which was natural since they were using it as a learning medium for the first time. However, over time at the second and third meetings, the observing aspect began to improve as students began to get used to the use of virtual labs. The same increase was also seen in the questioning and predicting aspects, where initially this aspect only reached 50.78%, then increased to 67.19% in the second meeting and 82.03% in the third meeting. This shows that students are starting to feel more confident and used to making hypotheses based on the problems presented.

The improvement of students' science process skills occurs because students begin to get used to doing practicum with the Kymatica Lab virtual laboratory. This is supported by the behaviouristic theory of B.F. Skinner which emphasizes that behavioural changes can be formed through repetitive and systematic reinforcement (Zahra & Rizal, 2024). At the beginning of using the virtual laboratory, students still experienced difficulties so their response was not optimal. But through continuous practice and giving positive feedback, they begin to get used to it and show improvement in those aspects of the skill. This phenomenon indicates that the learning process supported by consistent repetition and reinforcement is able to form better learning habits (Abidin, 2022).

The improvement is not only limited to the aspects of observation and hypothesis, but also includes other aspects. This improvement shows that the consistent use of Kymatica Lab's virtual labs is able to train all aspects of science process skills. Research by Rusdi et al. also supports this, which shows that virtual lab-based learning can improve students' science process skills and mastery of concepts with scores reaching 71%, 80%, and 90% in the implementation of practicums I, II, and III (Rusdi et al., 2021). Thus, the use of Kymatica Lab's virtual laboratory is considered practical in training students' science process skills.

Finally, the practicality of learning media was also assessed from the analysis of student response questionnaires to the use of Kymatica Lab's virtual laboratory based on the science process skills approach. These results can be seen in table 5 below:

Table 5. Recapitulation of Student Response Questionnaire

No.	Aspects Assessed	Shoes		Percentage
		Procurement	Maximum:	
1.	Interest	309	384	80.47%
2.	Understanding the Material	425	512	83.01%
3.	Overall Effect	292	384	76.04%
	Total	1026	1280	80.16%

(Source: researcher analysis)

Table 5, shows that the students' response to the media obtained a total percentage of 80.16%. Based on the practicality criteria in table 3, this figure is included in the practical category, which indicates that Kymatica Lab's virtual laboratory is very practical to use as a learning medium. The aspects assessed included the level of student interest (80.47%), understanding of the material (83.01%), and overall impression of practicum activities (76.04%). These results show that most students feel helped and motivated, making the learning process more fun and meaningful. They feel that these practicum activities are relevant and important in understanding the material, which ultimately increases motivation to actively participate and study independently. This is in line with the concept of intrinsic motivation according to *Self-Determination Theory* from Decy and Ryan. Intrinsic motivation *Self-Determination Theory* from Decy and Ryan explained that intrinsic motivation arises from within a person. It can be due to curiosity, interest, or satisfaction when learning (Fitriya et al., 2025).

In addition, the practicality of learning media based on student response questionnaires is also supported by research by Rina and Irma, which shows that the PraMetaVirLab application is able to become a very practical biology learning medium with a percentage of 83.3% (Rahma & Wardhani, 2024). The development of the virtual laboratory by Elisa et al., also received a good response, which was 96.8% and strengthened that virtual lab-based media is indeed very practical and suitable for use (Elisa et al., 2023).

Evaluation Stage

The evaluation is carried out comprehensively starting from analysis, design, development, to implementation, as presented in table 6 as follows:

Table 6. ADDIE Stage Evaluation

ADDIE Stages	What to do	Evaluation
Analysis	Carrying out observation and interview activities with science subject teachers at MTs Sunan Gunung Jati Gurah to understand the problems and needs of students in the school. In addition, the researcher also conducted an analysis to determine learning outcomes (CP) and learning objectives	The main problems found in the school include the limited tools for practicum activities, the low skills of students in conducting practicums, and the lack of use of learning media that is integrated with technology. As a solution, researchers developed a Kymatica Lab virtual

	(TP) from vibration, wave, and light materials.	laboratory based on a science process skills approach.
Design	Collect material in accordance with the CP and TP that have been set, as well as compile a storyboard as the basis for media development. In addition, the researcher designed validation instruments and other supporting tools such as science process skills questionnaires, student response questionnaires, learning modules, and observation sheets.	The product development plan has been prepared based on the analysis of student needs, learning outcomes, and learning goals to be achieved. The design also received evaluation from the supervisor before entering the next stage of development.
Development	At the development stage, the product and its supporting devices are made according to a pre-arranged design.	Validation of the products that have been developed is carried out by a number of experts to ensure that the products meet quality standards and are suitable for use as learning media. Based on the results of validation by experts, Kymatica Lab's virtual laboratory with a science process skills approach can be used as a learning medium.
Implementasi (Implementation)	The learning process using the Kymatica Lab virtual laboratory is carried out referring to the activities that have been designed in the learning module.	The results of the evaluation showed that the product met the eligibility criteria as a learning medium, where the Kymatica Lab virtual laboratory was considered feasible and could be used by all validators.
Evaluation	Evaluation activities were carried out through science process skills questionnaires and response questionnaires that were distributed to students after they used the media, accompanied by an evaluation of the product's strengths and weaknesses based on user experience. In addition, the implementation sheet is filled out by science	The results of the analysis of all assessment instruments, including implementation sheets, science process skills questionnaires, and student response questionnaires, showed that Kymatica Lab's virtual laboratory with a science process skills approach met the category of very practical as a learning medium. In addition, the level of

<p>teachers as observers of the course of learning.</p>	<p>students' enthusiasm in using the product is very high, because the material is equipped with pictures and videos so that the process of delivering the material becomes more interesting and effective. Although Kymatica Lab can be accessed offline, the use of materials and quizzes still requires an internet connection.</p>
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From the explanation above, it can be concluded that the development of Kymatica Lab which raises vibration, wave, and light materials through the science process skill approach is considered very feasible and practical to be used as a learning medium. In addition, this media is also able to increase the attractiveness and interactivity of the teaching and learning process. The findings are supported by the study of Marpu'a Tutdaroja, who also developed a virtual lab with Adobe Animate. The study shows valid and practical results from the development of virtual media as a learning medium for physics learning (Tutdaroja, 2022).

Conclusion

The Kymatica Lab Virtual Laboratory can be developed using the ADDIE model through five stages: *analysis, design, development, implementation, and evaluation*. Based on validation by media experts, material experts, learning experts, and virtual laboratory learning evaluation experts, Kymatica Lab is considered very feasible with a total percentage of 96.50%. The product was tested on 32 students and considered very practical as a learning medium with a total percentage of 84.75% reviewed from the implementation of learning, science process skills questionnaire, and student response questionnaire. It is hoped that this laboratory can be developed again with various materials to be more complete, interactive and interesting, including through training and improvement of the appearance, features and platforms used.

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