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Development of Creativity-Based Physics Lab Equipment: A New Solution for Deep Concept Understanding

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Abstract: This study aims to produce physics learning devices that can be used by students in carrying out physics practical activities in high school; so that their conceptual understanding of physics can be improved, as well as being able to increase their creativity in physics practical activities. Data collection was carried out through observation, questionnaires, interviews, and tests. Data analysis was processed qualitatively and quantitatively. Qualitative data processing was carried out through transcription, tabulation, coding, description, and analysis. Quantitative data was processed using N-gain based on pretest data and posttest data for the experimental and control classes. The effectiveness of the developed learning devices can be seen through the results of expert analysis and quantitative analysis of test results. The results of the study based on N-gain analysis showed thatThe developed high school physics learning device appears to be able to improve students' conceptual understanding and improve their creative thinking skills in experimenting by 0.49 in the moderate category.

Keywords: Creativity; Concept Understanding; Physics Lab

Introduction

Physics plays a crucial role in understanding the world around us and is a major driver of technological progress. As Niels Bohr said, "Physics is the language in which nature speaks to us, and scientists are trying to decipher its code." The history of physics can be traced back to ancient civilizations such as Greece, India, and China, from which the scientific method developed, and physics began to take shape as a science. Key figures such as Galileo, Kepler, and Newton laid the foundations of classical physics, which focused on the study of gravity, motion, and their laws. Physics is a science that has contributed greatly to the progress of nations, and work in physics is based on experimental methods to understand various natural phenomena (Benamer, 2024). However, various studies have revealed that many students face difficulties in understanding physics concepts and developing their problem-solving skills. For example, Snetinova & Koupilova, (2012) reported that only about 35% of students actually apply physics concepts when working on problems, and most students rarely create physics diagrams as part of their learning process.

Another difficulty that students often face is linking various physics concepts in an integrated manner. To overcome this, Holubova (2015) suggested that physics problems be linked to real-world situations, which is believed to improve students' understanding and interest in learning. However, a number of obstacles still remain, such as teachers' unpreparedness in implementing new learning methods and the negative impact of large class sizes on students' attention and participation (Williams, 2018). In addition, research suggests that girls tend to consider physics a more difficult subject than boys. This is likely influenced by a variety of factors, such as the classroom atmosphere and the quality of instruction received. Although physics has contributed greatly to technological development and economic progress, the subject remains a major challenge for many students, especially girls (Zulkiffli et al., 2024).

The results of the study in Malaysia showed that most schools with the number of students studying science subjects are still far below the targeted number. Most schools can only accommodate less than 40% of science students compared to art students. One of the main reasons identified as the cause of the low interest of science students is because science courses, especially Physics, are very difficult to learn (Mat Karim & Karim, 2024). Studies in Ghana show the same thing, where physics is considered the most problematic subject and is traditionally less popular with students. In addition, physics as a discipline or related activity that requires

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problem solving involving cognitive and emotional processes (Aboagye & Avor, 2025). The same performance also applies to students in Indonesia where interest in physics has decreased compared to other countries, namely Ireland (Sudirman et al., 2023). Most students consider Physics as a difficult subject, mainly because the learning process involved in understanding Physics requires students to deal with various types of representations, such as formulas, calculations, graphical representations, and also conceptual understanding at an abstract level (Angell et al., 2004). According to the research results, it was observed that, although students had an encouraging motivation to learn Physics, further analysis showed that most of them thought that studying the subject at school was not so interesting (Saleh, 2021).

Related to this problem, science education reform according to the National Research Council/NRC (2000) states that science learning (including physics) must prioritize the process of building concepts, principles, and the relationship of science to everyday life. NRC as an executive institution in the field of science and technology in America, explicitly suggests that the science learning process should prioritize teaching for understanding (Bodzin & Beerer, 2003).

According to NRC (2012), science learning in colleges and schools is identical to providing broad content. Although providing broad content is needed in understanding natural phenomena, it is not a single indicator to ensure that students have understood natural phenomena in their entirety through the observation process in science learning. Related to students' needs in everyday life, NRC has recommended three competency domains as the main individual ability factors to be developed; namely cognitive, intrapersonal, and interpersonal competencies; which include the development of students' creativity (Anjugam & Chellamani, 2024). If these needs must be focused in physics learning, it certainly requires a comprehensive understanding from physics teachers, through the learning plan that they prepare in the school's annual learning program plan.

So that learning is more focused, then Abrahams & Millar (2008) explains that practical activities must be designed in such a way by the teacher, so that students become more interested in learning in understanding a concept and increasing their creativity. Furthermore, such activities can also be called creative physics practical activities for high school students. Creative physics practical activities are expected to encourage high school students to think more broadly, formulate problems, test hypotheses, and solve problems in different ways, thereby increasing a deeper understanding of physics concepts (Heliawati et al., 2021). Especially for high school students, where in their learning they must have a deep understanding of abstract physics concepts but concrete phenomena; or concrete physics concepts but concrete phenomena (Jamaludin & Batlolona, 2021). The nature of students' understanding of scientific concepts and phenomena is an important component of education because students come to class with many alternative concepts that interfere with scientific principles and concepts (Ozkan & Topsakal, 2020).

This raises a critical question, why is that? This condition is caused by abstract and concrete concepts; it is difficult to do in practical activities, if the phenomenon is abstract. Take for example the concept of speed as an abstract concept, but the phenomenon is concrete; so the concept of speed is feasible in physics practical activities. In addition to abstract and concrete physics concepts, there are also physics concepts that are obtained empirically (Tomkelski et al., 2023). Another condition that occurs, if a concept is very large in size; then it is difficult to do in physics practical activities. For example, it is focused on the process of measuring the radius of the earth. Although the concept is concrete and the phenomenon is concrete; however, the concept of measuring the radius of the earth is difficult to practice in the laboratory, because the concept is very large (Ladd et al., 2019). This study aims to produce physics learning tools that can be used by students in carrying out physics practical activities in high school; so that their conceptual understanding of physics can be improved, as well as being able to increase their creativity in physics practical activities.

Method

This research was conducted, referring to the research and development design according to Gall et al. (2003), namely: (1) Preliminary study; (2) Program design; (3) Program development; and (4) Program validation. The method used in this study was a pre-experiment with a one group pretest-posttest design (Creswell, 2007) as seen in Figure 2. Before starting learning with the designed lecture program (X1), students were given a test to evaluate their creative thinking skills in experimenting (O). After the learning process was completed, the smoothness of the implementation of the use of the device was evaluated through observation results, and the increase in student creativity was measured again with a creative thinking skills test in experimenting (O). The research subjects consisted of a total of 125 students and there were limited trials of 2 classes, and implementation of 2 classes. Limited trials in class 11 had 2 classes. The number of students in the trial class was 30, 31; while the implementation class was 32, 32 at SMA Negeri 2 Ambon. Before the treatment (X1), students were given a test to measure creative thinking skills in experimenting (O). After the learning process was completed, the implementation of the use of the device was assessed through observation, and creative thinking skills were re-measured through the same test. The measuring instruments used in this study consisted of creative thinking skills test questions in experimenting, observation sheets, questionnaires, and interview guidelines. The test consisted of six items to measure students' competencies related to their ability to explore the lab equipment kit, develop variations of labs for the same concept, and design labs in physics learning. There are four aspects of students' creative thinking skills measured through the test, namely fluency, flexibility, originality, and elaboration, which are adapted from creative learning literature (Guilford, 1988). This test also measures indicators of scientific thinking skills such as formulating practical topics, setting goals, compiling theoretical basis, basic principles, setting tools, practical procedures, data collection techniques, and data analysis techniques. Students' conceptual understanding is measured based on the revised Bloom's taxonomy according to Krathwohl (2002), with indicators in the form of the ability to provide examples, classify, and explain. Quantitative data analysis on improving understanding of physics concepts and creative thinking skills was obtained through normalized gain calculations (<g>) (Hake, 1998). The percentage of student and teacher learning implementation was analyzed from the results of observations on each indicator assessed by the observer according to the Saul & Redish (1998) method. Data from the questionnaire and interview guidelines that collected information from teachers, lecturers, and prospective physics teacher students were analyzed quantitatively and qualitatively. These data were previously transformed using the Method of Successive Interval (MSI) as a prerequisite for statistical testing (Hays, 1976).

Results and Discussion

The improvement of students' creative thinking skills in experimenting as a basic thing that brings out their creativity, can be seen based on the achievement of each skill indicator in experimenting with students' creative thinking skill activities. The normalized average gain (<g>) of students' creative thinking skills for the achievement of each skill indicator in experimenting with their creative thinking skill activities showed an increase of 0.49 in the moderate criteria as shown in Table 1. This achievement occurred because there were differences and similarities between the posttest scores and students' pre-test scores for each skill indicator in experimenting with their creative thinking skill activities. The data in Table 1 is in line with the findings of previous studies that the results of limited trials obtained an average n-gain value of 0.46. Based on the results of the feasibility test, user trials, and limited trials, it can be concluded that the developed LKS is very suitable for use as a learning tool in physics practicum activities in grade X of high school. Student worksheets with the discovery learning model and equipped with AR videos are needed as learning media (Bakri et al., 2020).

The students' mistakes in designing the practicum design indicate that the developed device must be improved. The scientific activities that have been trained so far have not been able to be applied optimally by a number of students. In addition, physics experiments in high schools play a very important role in fostering students' scientific thinking and scientific investigation abilities. However, in teaching practice, due to large experimental errors, poor demonstration effects, and lack of experimental conditions, students cannot achieve the expected teaching effects (Ma et al., 2021). The stage of experimental activities towards high-level thinking according to Wenning & Vieyra (2020)as a learning pattern in the physics laboratory that has been explained in the teaching materials, has not been fully followed by students. A review of the substance of the experiment, it appears that students have not been optimal in observing a phenomenon that is not only located in the experiment, but also depends on the way of thinking about how to explain the cause-effect relationship of the phenomenon.

In other words, the process of observing is not only using the physical eye but also the mind's eye. The theoretical basis related to the development of physics experimental learning programs requires students' mental processes adapted from the transformation of knowledge. Research results Trna & Novak (2014)about effective motivation towards practical work in physics education supports the findings of this study, which shows that practical activities organized by teachers or carried out by prospective physics teachers are not always appropriate and sufficient for the development of students' skills and knowledge in studying physics.

The main indicators that determine the quality of students' education include their ability to solve problems and see things from a critical perspective (Khan & Rauf, 2024). Students' ability to solve problems is highly dependent on their conceptual understanding of various materials. In the last ten years, these aspects have been widely studied and analyzed (Bahar & Aksut, 2020). In addition, teacher commitment and performance can be measured through student academic achievement data, while students' mastery of concepts and problem-solving abilities have a direct relationship to their academic success. High levels of academic achievement are generally closely related to the mastery of adequate knowledge, skills, and abilities (Saroyan & Trigwell, 2015). Thus, the understanding of the concept and aspects of creative thinking skills or the manifestation of their creativity that needs to be provided, must be applied based on the basis of cognitive learning theory; while behavioral learning theory is used to facilitate students in developing their practical activities in the laboratory (Sultan & Marisda, 2024).

Previous studies also showed consistent performance, namely, there was an increase in the aspect of students' creative thinking skills for each indicator of activities in experimenting at moderate criteria; as well as an increase in students' understanding of basic physics concepts for the indicators of exemplifying, classifying, and explaining at moderate criteria. It was concluded that the developed physics experiment lecture device could increase students' creativity in designing physics practicum activities based on measurable material coverage (Wattimena et al., 2014).

Table 1. Recap of the Results of the Implementation of Creative Physics Learning Tools

AKBK	IKDB	Before Implementation				After Implementation			
		Test Beginning	Test End	<g>	Category	Test Beginning	Test End	<g>	Category
Smoothness	Practical topics	43.61	68.60	0.44	Currently	23.90	77.90	0.71	Tall
	Objectives of the practicum	40.82	66.33	0.43	Currently	26.90	80.30	0.73	Tall
	*Set up*equipment	11.62	47.86	0.41	Currently	20.10	61.20	0.51	Currently
Flexibility	Practical topics	16.11	43.79	0.33	Currently	24.70	58.70	0.45	Currently
	Objectives of the practicum	15.70	44.83	0.35	Currently	25.60	63.90	0.51	Currently
	*Set up*equipment	16.32	47.31	0.37	Currently	23.40	55.40	0.42	Currently
	Tools and materials	10.33	51.87	0.46	Currently	25.10	67.70	0.57	Currently
	Data collection techniques	13.34	39.30	0.30	Currently	21.50	57.90	0.46	Currently
	Data analysis techniques	12.35	40.11	0.32	Currently	21.60	56.10	0.44	Currently
Originality	Practical topics	11.32	43.61	0.36	Currently	20.70	60.40	0.50	Currently
	Objectives of the practicum	13.43	49.44	0.42	Currently	22.30	59.00	0.47	Currently
	*Set up*equipment	9.91	39.34	0.33	Currently	15.50	46.70	0.37	Currently
	Tools and materials	9.35	47.15	0.42	Currently	17.20	62.10	0.54	Currently
	Practical procedures	16.67	48.16	0.38	Currently	17.60	58.70	0.50	Currently
	Data collection techniques	10.40	41.60	0.35	Currently	15.80	47.50	0.38	Currently
	Data analysis techniques	17.69	45.14	0.33	Currently	16.60	46.70	0.36	Currently
Elaboration	Basic theory	18.72	46.34	0.34	Currently	15.20	57.70	0.50	Currently
	Basic principles	23.25	48.20	0.33	Currently	12.60	45.50	0.38	Currently
	Practical procedures	20.22	53.91	0.42	Currently	14.20	59.70	0.53	Currently
Average		17.43	48.05	0.37	Currently	20.03	59.11	0.49	Currently

Physics lessons that are only taught theoretically in class are one of the causes of students' negative attitudes towards the lesson. Therefore, abstract concepts in physics need to be linked to students' daily lives and delivered through simulations, animations, and videos in order to actively attract students' attention. Learning that involves self-discovery is considered more effective than just passive listening, so it is important to show how physics concepts are connected to students' daily activities. Instead of increasing physics laboratory hours, it would be better to develop science experiments that can be done directly by students in an interesting way and using simple materials (Kaya & Boyuk, 2011).

Physics experiment simulation began to develop along with the advancement of modern educational technology. In the late 1980s, the Massachusetts Institute of Technology in the United States began developing a simulation laboratory and succeeded in creating a web-based simulation experiment system, which was introduced for learning purposes in 1988. In his 2000 book "Simulation Experiment Design", W. David Kelton highlighted the significant benefits of using simulation experiment design in physics experiments and advocated for the popularization of this method (Li, 2024). At present, simulation experiments are widely applied in university physics laboratories in China. Basically, physics simulation experiments follow the laws of physics development. In the course of physics progress, the formulation and delivery of physics concepts require many experiments for verification and analysis, so physics is known as a science that is very experimentally based (Huang et al., 2014). Simulation experiments present the physics experiment process in a more understandable, practical, and fast way. Its characteristics include high efficiency, ease of understanding, low operational costs, and a high level of safety. The main benefits of simulation experiments are providing a clearer picture of the experimental process, more accurate data, improving students' ability to conduct computer-based virtual experiments, and raising awareness of the importance of innovative thinking among students.(Hamed & Aljanazrah, 2020). In addition, virtual laboratories significantly improved metacognitive self-regulation, effort regulation, peer learning, and overall learner self-regulation more than physical laboratories (Al-Duhani et al., 2024).

The implementation of creative physics learning devices that get a moderate category assessment generally indicates that the application of the device in the teaching and learning process has not fully provided optimal results, but has not failed completely either. This moderate category status reflects the existence of a number of factors that influence the effectiveness of the use of the device so that the results achieved are at a moderate level.

Creative physics learning tools are usually designed with innovative elements and aim to make learning more interesting and easier to understand. However, in practice, the materials or media provided may not be fully effective in reaching various types and learning styles of students optimally. In addition, some creative activities that are expected to increase student engagement may still be less than optimal or not fully integrated.

The success of implementation is highly dependent on the teacher's ability to operate the learning device. In some cases, teachers may not have received adequate training or may not be fully confident in using new media and methods. The habit of using conventional methods can also be an obstacle, so that creative learning devices are not optimally absorbed in the learning process.

Students who have different levels of initial ability, interests, and learning motivation also affect learning outcomes. Students who are less motivated or have difficulty relating physics concepts to real-world contexts may not be able to get the full benefit of the creative learning tools. This makes the achievement of learning objectives less than optimal and has an impact on the moderate outcome category.

Creative learning often requires supporting facilities such as adequate practical tools or interactive media. If the school has not provided these facilities adequately, the use of creative learning devices will be less than optimal. A less conducive learning environment, such as a class that is too large, also reduces the opportunity for teachers to provide personal attention and guidance to students.

Ineffective evaluation mechanisms and the lack of constructive feedback are also among the causes of moderate implementation results. Without regular evaluation and revision of devices based on these results, the quality of learning devices does not experience significant improvement according to student needs and learning process conditions.

The moderate category in the results of the implementation of creative physics learning devices reflects the potential and efforts that have been carried out, but there are still weaknesses in various aspects, ranging from the quality of the devices, teacher readiness, student characteristics, school facilities, to evaluation mechanisms. With attention and development in these areas, the results of the implementation can be improved to a good or even very good category, so that physics learning becomes more effective and interesting for students.

Conclusion

Based on the results of the analysis of the implementation of the learning program through the devices that have been developed, it turns out that the scope of physics concepts as a prerequisite for learning is the main cause of errors for some students. The achievement of increasing students' creative thinking skills as a manifestation of their creativity in designing practical activities cannot be separated from learning interventions that provide space for them.to work collaboratively and individually. In this process, students have learned productively to construct their knowledge based on the ideas that have emerged about how to design physics practical activities.

The findings of this study indicate that the developed learning devices can provide meaningful learning progress for students so that they can train them to think in various ways. The improvement of the creative thinking skills aspect of students' fluency is more influenced by their activities guided through the learning program devices for each activity indicator in experimenting through guided practice learning patterns. These results support the findings of the study Cheng (2010) showed that there was a significant increase in student creativity in the fluency aspect; after they were given treatment through practical instructions with a guided practice learning pattern.

The results of the analysis also show that some students who are not maximally active at the general explanation stage and group discussions have the potential to conduct analysis based on their own reasoning to complete individual tasks; which does not refer to the results of scientific observations and analysis. This is in line with Danielsson's (2011) explanation that physics practicum activities will have an impact on students' discourse models based on the implementation of practicums and analysis, based on their own reasoning and experience of basic physics concepts while doing activities.

Based on these findings, it is suspected that the creative physics learning device developed for students at one of the high schools in Ambon City, should not be oriented to intermediate physics concepts. This is based on the design of the students' practicum which turned out not to be directed at the substance of the concept in question. This suspicion is reinforced by the results of a limited trial applied to students who have studied intermediate physics material; which turned out that they were also not able to design a practicum on intermediate physics concepts. These findings also show that there is an increase in students' creative thinking skills in experimenting based on the achievement of each indicator of activities in experimenting towards aspects of their creative thinking skills. The normalized average gain (<g>) of students' creative thinking skills for the achievement of each indicator of activities in experimenting towards aspects of their creative thinking skills shows an increase of 0.49 in the moderate criteria as shown in Table 1. This achievement occurred because there were differences and similarities between the posttest scores and students' pre-test scores for each indicator of activities in experimenting towards aspects of their creative thinking skills.

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