EXPERIMENTS DESIGN IN THE ORGANIZATION OF PHYSICS TEACHING TO FORM AND IMPROVE STUDENTS' PRACTICAL CAPACITY

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ARTICLE INFO

Received: 03/6/2024
Revised: 25/9/2024
Published: 25/9/2024

KEYWORDS

Capacity
Practical capacity
Electromagnetic Induction
Experiments Design
Self-created experiment
Teaching Physics

ABSTRACT

The designing experiments in the organization of teaching Physics plays an important role. At the same time, using designed experiments in teaching is not only a means of organizing students' cognitive activities but also contributes to fostering students' practical. Therefore, we designed some experiments from the chapter "Magnetism and Electromagnetic Induction", 12th grade Physics program of Lao PDR and used these experiments in Physics teaching to develop practical capacity for students. These designed experiments are created mainly by hand from common materials and components in in daily life. Through the use of designed experiments, students have the opportunity to make suggestions and conduct experiments. In this article, We have proposed the process for designing and using experiments in teaching the knowledge of the chapter "Magnetism and Electromagnetic Induction" 12th grade Physics. The results of the pedagogical experiment show that the process of designing and using experiments helping students develop of practical capacity in teaching Physics at high schools, Lao PDR.

THIẾT KẾ THÍ NGHIỆM TRONG TỔ CHỨC DẠY VẬT LÝ ĐỂ HÌNH THÀNH VÀ NÂNG CAO NĂNG LỰC THỰC HÀNH CỦA HỌC SINH

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THÔNG TIN BÀI BÁO

Ngày nhận bài: 03/6/2024
Ngày hoàn thiện: 25/9/2024
Ngày đăng: 25/9/2024

TỪ KHÓA

Năng lực
Năng lực thực hành
Cảm ứng điện từ
Thiết kế thí nghiệm
Thí nghiệm tự tạo
Dạy học Vật lí

TÓM TẮT

Thiết kế thí nghiệm trong tổ chức dạy học Vật lý có vai trò quan trọng, đồng thời khi sử dụng thí nghiệm đã thiết kế không chỉ là phương tiện tổ chức hoạt động nhận thức mà còn góp phần bồi dưỡng năng lực thực hành của học sinh. Vì thế, chúng tôi thiết kế một số thí nghiệm trong chương “Từ trường và Cảm ứng điện từ”, Vật lý lớp 12 Trung học phổ thông, nước Cộng hòa Dân chủ nhân dân Lào và sử dụng trong dạy học nhằm phát triển năng lực thực hành cho học sinh. Các thí nghiệm được thiết kế chủ yếu được tạo ra bằng tay, từ các vật liệu, linh kiện thông dụng trong đời sống hàng ngày. Thông qua việc sử dụng thí nghiệm tự tạo, học sinh có cơ hội đưa ra đề xuất, tiến hành thí nghiệm. Trong bài báo này, chúng tôi đã đề xuất quy trình thiết kế và sử dụng thí nghiệm trong dạy học kiến thức chương “Từ trường và cảm ứng điện từ” Vật lý lớp 12. Kết quả thực nghiệm sư phạm chỉ ra rằng quy trình đã xây dựng giúp học sinh khắc sâu kiến thức đồng thời góp phần phát triển năng lực thực hành trong dạy học Vật lý THPT, nước Cộng hòa Dân chủ nhân dân Lào.

DOI: https://doi.org/10.34238/tnu-jst.10531

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1. Introduction

Physics is an experimental science. Therefore, most of the knowledge of physics is derived from observations and experiments. The use of experiments and the use of designing experiments in teaching physics is an indispensable requirement. The necessity of using experiments in research in general and teaching physics, in particular, is also determined by the general law of human perception that Lenin has shown: *"From intuition to abstract thinking and from abstract thinking to practice is the way to perceive the truth, to perceive objective reality"* [1]. It can be said that experiments always play a very important role in teaching physics in high schools. However, the experiments in the list of minimum laboratory equipment provided, only partially meet the needs of using experiments in teaching physics in high schools. Therefore, it is very necessary to build and use self-created experiments in teaching physics [2], [3]. Moreover, with the advantages of being easy to operate, easy to carry out, as well as self-created experiments that do not require strict conditions on facilities, it is possible to conduct experiments anywhere, anytime. It is easy to promote the role of self-created experiments in teaching Physics [4], [5]. Thus, the study of using self-created experiments in teaching has always been a key issue in the trend of finding ways to improve the effectiveness of physics teaching in high schools today. The study, design, manufacture, and use of self-created experiments not only help students deepen their knowledge, but also help train students with practical skills and techniques, such as proposing experimental plans; processing, assembling, conducting experiments; Collect, process, and drawing conclusions, thereby contributing to the development of practical capacity for students in teaching physics in high schools [6].

Education Strategy of the Lao Ministry of Education & Sports (2020) and the Education Strategy of the Ministry of Education & Training of Vietnam all affirm a strongly shifting from teachers' lecture-heavy teaching methods to active teaching methods to form skills; increase personal activity; attach importance to skill training as equal to knowledge transmission; increase exploitation, use experiments and visual aids in teaching [7] - [9]. In Europe, especially in Germany, many authors have been interested in research self-created experiments such as Michael Völlmer, Klaus Peter Möllmann (2011); Hans-Jörg Jodl and Bodo Eckert (1998); Hans-Joachim Wilke (2004) and D.K. Nachtigall, J.Dieckúfer, G.Peters (1996) [10] - [13]. The authors have researched on self-created and used self-created experiments in teaching most of the parts such as: Mechanics, Thermodynamics, Electricity, Optics… Most self-made experiments are made simply from cheap materials, easy to find: soft drink cans, water bottles... [14].

When studying the current situation of using Physics experiments by teachers in some high schools, it showed that: The reason why teachers have difficulty in teaching is that some schools do not have laboratories and the teacher could not conduct the experiment for lack of experimental equipment and thereby recommending that teachers should experiment with simple, cheap and easy-to-find materials to use in teaching.

From the above analysis, researching the construction and use of designed experiment in teaching physics in high schools is very meaningful scientifically and practically in the context of teaching the chapter "Magnetism and Electromagnetic Induction" Physics Grade 12 High School of Lao PDR, thereby contributing to the effective implementation of the 9th Education Strategy (2021–2025) of Lao PDR.

2. Research method

The topic uses a combination of research methods: theoretical research (analyzing and synthesizing theories related to the research problem); Practical research (observe lessons, refer to teacher lesson plans, interview, survey using questionnaires); Experimental methods of pedagogy and mathematical statistics.

3. Results and Discussion

3.1. Results of practical investigation

Survey results of 22 Physics teachers and laboratory managers in Pakse City, Champasak province, Laos show that: teachers do not often use experiments, the reason is because Experimental tools lack uniformity. In addition, when being asked about the quality of the experimental equipment in the chapter "Magnetism and Electromagnetic induction", 45.4% of teachers said that the quality was not guaranteed, and 22.7% of teachers said that the experimental equipment was not consistent. 18.1% of teachers think that the equipment is damaged and cannot be used and only 13.6% of teachers think that the equipment is equipped with quality assurance. In addition, Physics teachers also believe that using experiments in teaching physics is very necessary, contributing to the development of students' practical capacity. The survey results show that 72.7% of teachers think that using experiments in teaching physics is very necessary. And when asked about the use of self-created experiments in teaching physics, more than 81% of teachers said that they only create their own experiments when participating in teaching aid competitions and when there is a certain program organized. Nearly 14% of teachers think that they only create their own experiments when teaching and more than 4% of teachers use it for daily teaching. In addition, we also conducted a survey on the level of interest in learning Physics of 280 grade 12 students. The number of students who said they liked it when teachers used self-created experiments in teaching physics accounted for 45.5% and 55% of students feel normal when teachers use self-created experiments.

3.2. Results of theoretical basis

3.2.1. The process of Self-created experiments

Based on research on design experiments, we propose the process of design experiments according to the following steps:

Step 1: Determine the experimental goal

Objectives of the Experiment are expressed through 3 elements: knowledge, skills and attitudes. Therefore, it is necessary to clarify the use of design experiments to form what knowledge and abilities for students.

Step 2: Research the lesson content and then propose an experiment plan

On the basis of researching teaching objectives and lesson content, teachers need to determine which knowledge content in the lesson can create their own experiments to form knowledge for students. On that basis, teachers can propose appropriate experimental plans.

Step 3: Find out the current condition of the facilities and prepare materials

Through understanding the current state of the facilities, point out which experiments already exist and which experiments need to be created for use in teaching.

Step 4: Machining, manufacturing experimental equipment

From the prepared materials, we proceed to process and manufacture experimental equipment and they must ensure that they meet the requirements.

Step 5: Assemble the experimental kit

After completing the processing of the necessary experimental tools, the next step is to assemble the experiment according to the proposed plan. Assembling the experiment requires care and precision to ensure feasibility and accuracy.

Step 6: Test and complete the experiments

Check for errors and defects during the machining process to fix unsatisfactory problems, to enhance the visualization, aesthetics, and durability of the Experiment Set and ensure it can be used many times. Figure 1 describes six step of the process of design experiments to develop of practical capacity in teaching Physics.

Step 1: Determine the experimental goal

▼

Step 2: Research the lesson content and then propose an experiment plan

▼

Step 3: Find out the current condition of the facilities and prepare materials

▼

Step 4: Machining, manufacturing experimental equipment

▼

Step 5: Assemble the experimental kit

▼

Step 6: Test and complete the experiments

Figure 1. *The process of design experiments*

3.2.2. Design experiments in teaching chapter: Magnetism and electromagnetic induction

Experiment:

Magnetic force acting on an electric current in a magnetic field

a) Experiment purpose:

- Show that there is a magnetic force acting on an electric current placed in a magnetic field.
- Check the left-hand rule.

b) Proposing and selecting experimental plans:

Proposing some experimental plans to prove that there is a magnetic force acting on a current-carrying wire when placed in a magnetic field and choose the most feasible option to conduct self-created experiments Figure 2.

c) Prepare materials, Experimental equipment:

- 01 Copper round bar (Long 50 cm, Diameter 1 mm); 01 Battery 6V; 02 Wire; 01 Magnet U.
- 01 Round wooden bar (Long 20 cm, Diameter 2 cm); 02 Screws; 01 Pieces wood (20 cm x 25 cm x 2 cm); 02 Support legs; 01 Switch.

d) Machining, manufacturing experimental equipment:

- Processing and assembling the hanging stand as shown in (1): screw on one side of two round wooden bars, then attach it to the wooden board as a support.
- Making hanging rails (2): Bend the copper bar into a U shape to fit the hanging base.

e) Assemble the experimental kit

Hang the U-shaped copper rod (2) on the hanging base (1) and place the U-shaped magnet so that the copper bar is in the center of the Magnet as shown in (3) and install the battery to form an electrical circuit, we have the experiment as follows on Figure 2.

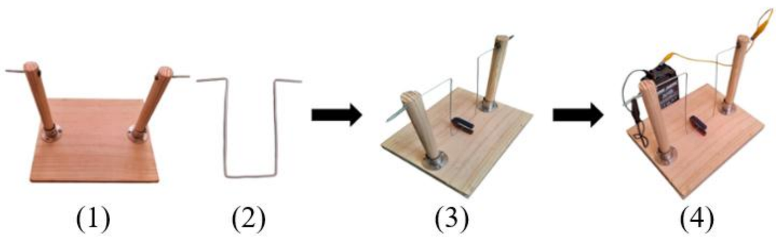

Figure 2. *Design experiments about Magnetic force acting on current in a uniform magnetic field*

f) Test and complete the experiments

Conduct a test: Open the power switch, observe that the copper rod is pushed out of the equilibrium position forward, reverse the direction of the current, then observe that the copper rod is pushed out of the equilibrium position in the direction opposite. Through experimenting, detecting limitations to overcome to ensure the most obvious results, thereby completing the experiment: *Magnetic field acting on a moving charge* as shown in Figure 2.

Similarly, based on the above procedure, we have created some other experiments in Chapter "Magnetism and electromagnetic induction" Physics 12 including (Figure 3):

Experiment 1: The relationship between electricity and magnetism
Experiment 2: Magnetic interaction of a charge-carrying wire
Experiment 3: Magnetic field lines
Experiment 4: Magnetic field lines of long straight current
Experiment 5: Magnetic field lines of circular current
Experiment 6: Magnetic field lines of the current flowing through the coil
Experiment 7: Magnetic force acting on a magnet
Experiment 8: Magnetic force acting on an electric current placed in a magnetic field
Experiment 9: Interaction force between two parallel straight currents
Experiment 10: Model of a DC motor
Experiment 11: The phenomenon of electromagnetic induction when the magnet and the wire are moving with respect to each other
Experiment 12: The phenomenon of electromagnetic induction when the current in the coil changes
Experiment 13: Foucault current
Experiment 14: Electromagnetic brake model
Experiment 15: self-inductance phenomenon when on the circuit
Experiment 16: Self-inductance phenomenon when the circuit is cut off

Figure 3. *Design experiments to teach Chapter "Magnetism and electromagnetic induction"*

3.2.3. The process of organising teaching with the use of experiments design

In teaching physics, experiments design can be used at different stages in the teaching process, such as: proposing the problems, solving the problem, and consolidating and applying knowledge (Figure 4).

When using experimental design in physics teaching, it is necessary to master the following requirements:

- Clearly define experiments design to be used at any point in the teaching process. It is necessary to determine that the purpose of using experiments in the lesson is to propose problems, form new knowledge or consolidate and apply knowledge.

- It is necessary to determine whether the experiment is conducted by the teacher or the students: if the teacher conducts the experiment, before conducting the experiment, it is necessary to introduce the students to the purpose of the experiment, the steps of the experiment and the tasks of the experiment. If the students conduct the experiment, it is necessary to introduce the students to the experimental equipment, instructions on how to assemble it, the steps of the experiment, how to record and process the results and draw conclusions.

- Careful preparation of the experiments is required to ensure successful experiments during class time.

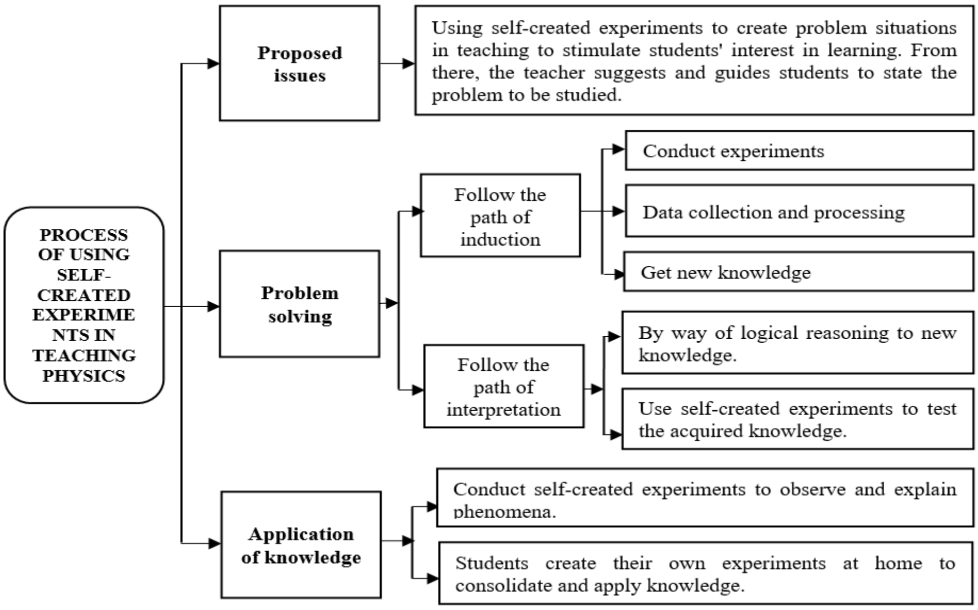

Figure 4. *Teaching process with the support of design experiments*

3.2.4. Evaluate students' ability to practice capacity physics

To evaluate students' practical ability when using design experiments in physics teaching, we evaluate based on 5 proposed criteria through the Rubric table and evaluate each lesson, the score for each individual student is given based on 5 levels of student skill formation. Then take the average score (X) of the 5 criteria achieved by the individual student to evaluate the practical ability and classify it into 4 levels. *(If: $X \geq 8$ = Very Good; If: $6{,}5 \leq X < 8$ = Good; If: $5 \leq X < 6{,}5$ = Medium; If: $X < 5$ = Low).* Table 1 describes of the criteria for assessing students' practical capacity in Physics. Table 2 describes the scoring table for assessing the level of skill formation of each student.

Table 1. *The set of criteria for evaluating students' practice capacity in Physics*

Criterion 1: Design an experimental plan	
Level 1	The purpose of the experiment cannot be determined, the necessary tools cannot be proposed, and a plan for conducting the experiment cannot be designed. Teachers need to provide models for students to imitate and copy the teacher's steps.
Level 2	Know how to identify the purpose and propose experimental equipment but not fully. The plan has been designed but is still sketchy, the experimental plan lacks feasibility, still needs the direction and guidance of the teacher.
Level 3	Know how to determine the purpose and fully propose the tools of the experiment but have not made it clear. Know how to build a feasible but not optimal experimental plan that needs correction, adjustment, supplementation, and teacher's suggestions.
Level 4	Determine and accurately state the purpose, fully and accurately propose the experimental tools. Present the most optimal experimental plan scientifically and clearly within the prescribed time without the need for teacher support or intervention.
Level 5	Determine and accurately state the purpose, fully and accurately propose the experimental tools. Present fully and in detail the most optimal experimental plan scientifically in a short time.

Criterion 2: Manufacturing experimental instruments	
Level 1	It is not known how to manufacture experimental tools according to the proposed plan.
Level 2	Initially know how to design some simple experimental tools but need detailed instructions from the teacher.
Level 3	Knowing how to design some experimental tools, but the aesthetic and technical qualities are not high, teachers need to improve and supplement.
Level 4	Fabricate experimental tools suitable to the selected plan, and ensure aesthetic and technical quality without needing additions or comments from the teacher.
Level 5	Designed experimental equipment in accordance with the proposed plan, ensuring high aesthetic and technical quality and completed in a short time.
Criterion 3: Know how to use and repair laboratory tools	
Level 1	Students do not know the name of the tool, what quantity to measure, and how to repair damage. Teachers need to model operations using tools for students to follow and perform those operations.
Level 2	Initially learning about tools, performing operations using tools and not knowing how to repair them, requires detailed and meticulous guidance from the teacher.
Level 3	Know how to learn about tools through direct observation, know the name of the tool and the meaning of the parameters recorded on the measuring tool. Can operate on their own and know how to repair some common damage to tools without much support from teachers.
Level 4	From directly observing the tools and reading the instructions, students can learn about new tools, operate the tools within the prescribed time, and know how to repair the tools without the teacher's guidance.
Level 5	Learn a new tool, know how to use it, and know how to operate the tool fluently in a short time.
Criterion 4: Assemble and conduct experiments	
Level 1	Don't know how to disassemble and assemble tools according to the diagram, need teacher's modeling to imitate and follow.
Level 2	Know how to assemble the tools under the meticulous guidance of the teacher, arrange the experiment according to the diagram provided in the instruction manual, but the operation is still confusing.
Level 3	Know how to assemble and arrange experimental tools according to the diagram but the time is not guaranteed, the teacher needs to adjust accordingly.
Level 4	Know how to assemble tools and arrange experiments correctly without the teacher's instructions and within the prescribed time.
Level 5	Know how to assemble tools accurately and skillfully at high speed, arrange tools in accordance with theory, in a short time and ensure safety.
Criterion 5: Accurately collect and process data and results	
Level 1	Don't know how to choose a scale or adjust tools. To collect data and how to process the data according to graphs or not be able to calculate the errors yourself, need pre-existing error calculation formulas and also comment on the results according to the given form.
Level 2	Know how to choose measuring scales, know how to adjust instruments, collect and process data under the detailed and meticulous guidance of teachers. But students do not understand the physical and practical meaning of the results. To explain the problem posed at the beginning.
Level 3	Know how to choose measuring scales, adjust tools properly, know how to collect and process data, but it's still slow, you have to do it many times to get results. And the actual physical meaning of the results is not clearly understood to explain the problem posed at the beginning.
Level 4	Choose the correct scale, adjust accurately, correctly read the data collected on the instrument according to the prescribed error, know how to handle data by calculating errors or drawing graphs within the specified time. Understand and explain the practical physical meaning of the conclusion.
Level 5	Choose the right measuring scale, adjust instruments accurately and quickly, collect and process data accurately and quickly. Know how to process data by calculating or drawing graphs. Understand and accurately explain the practical Physics meaning of the conclusion.

Table 2. *Rubric evaluates students' practical capacity*

Criteria	Level of practical competence					Scores
	Level 1	Level 2	Level 3	Level 4	Level 5	
	2	4	6	8	10	
Design an experimental plan						
Manufacturing experimental instruments						
Know how to use and repair laboratory tools						
Assemble and conduct experiments						
Accurately collect and process data and results						
Average score (X)						

3.3. Results and Discussion

We conducted pedagogical experiments on a sample of 287 students from 8 classes at 4 high schools in Pakse city, Champasak province. Thereby collecting and processing data to evaluate the development of students' practical capacity through the use of designed experiments.

3.3.1. Qualitative assessment

All lessons progress and students' learning activities in experimental classes (using designed experiments) are observed, from which the following comments are drawn:

- In the first period, most students are confused, passive, and hesitant to contribute ideas. They are not familiar with proposing plans, conducting experiments, as well as processing results, and drawing conclusions. In the following lessons, the students were bolder and more active in performing the learning tasks and began to know how to propose and choose experimental plans, how to assemble and conduct experiments.
- Students in the experimental class are quite interested in self-created experiments because they are encouraged to propose their plans, make tools, assemble, conducting experiments by themselves.
- The practical capacity of students has been improved through each lesson, demonstrated through operations such as machining, assembling, conducting experiments, collecting and processing data more and more proficiently.

3.2.2. Quantitative results

To evaluate practical capacity when using designed experiments in teaching, we monitored and observed students' activities in lessons. On the basis of monitoring and observing teaching activities in 5 teaching processes, we randomly selected 3 students from each class to be placed in groups to evaluate the development of individual students' practical abilities. Evaluation is based on the criteria through the Rubric table and the results are as follows. Table 3 describes the results of the assessment of students' practical capacity through the use of designed experiments.

Table 3. *Results of the assessment of students' practical capacity through the use designed experiments*

Lessons	Students	Level of practical competence			
		Low (%)	Medium (%)	Good (%)	Very good (%)
12	12	33.3	50.0	16.7	0
13	12	25.0	33.3	33.3	8.3
14	12	8.3	33.3	41.7	16.7
15.1	12	0	25.0	50.0	25.0
15.2	12	0	16.7	50.0	33.3

The results of the assessment of students' practical capacity show that, initially when using the designed experiment, students' practical capacity is mostly at low and average levels, no student achieved a good level of practical ability. But in the following lessons, the students achieving good and very good levels of practical ability increased and vice versa, students achieving low levels of practical ability and the medium level decreased. This shows that through lessons using designed experiments, the practical capacity of individual students is developed. Figure 5 describes the development of each student's practical capacity through lessons.

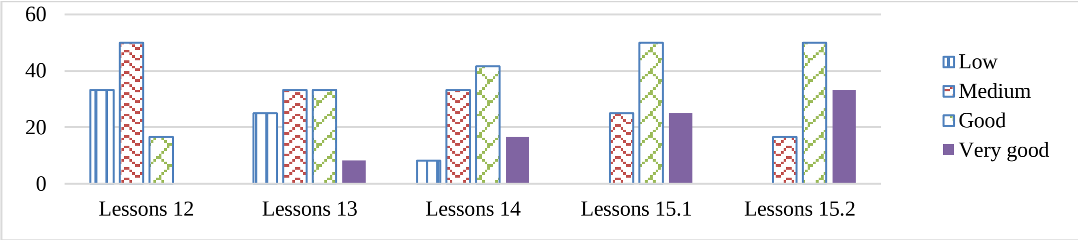

Figure 5. *The development of individual students' practical capacity through lessons*

4. Conclusion

In this study, we have built 16 designed experiments and used them in 5 teaching processes in the Chapter "Magnetism and Electromagnetic Induction" 12th grade Physics of Lao PDR. The experiments and teaching process are designed to foster practical capacity for students to be feasible and effective in the physics teaching process. When using designed experiments in teaching process, it makes class time lively and students are excited to perform learning tasks in each stage of the teaching process, they solve problems faster and better, and state the phenomena in real life, production and science. The research results obtained show that the construction and use of designed experiments in teaching Physics in the direction of developing practical capacity of students in high schools of Lao PDR is feasible, consistent with the current education strategy of Lao PDR.

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