Building and Using Self-Created Experiments in Teaching Physics to Develop Students' Practical Capabilities – A Study in the Chapter "Magnetism and Electromagnetic Induction"

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***Abstract*—Self-created experiments are experiments that are created mainly by hand from raw materials, devices, and common components in daily life and used in the teaching process. Using self-created experiments in teaching will give students more opportunities to participate in learning activities. Therefore, it is not only a means to organize students' cognitive activities but also contributes to fostering students' practical ability in teaching physics in high school, because through creating and using experiments students have the opportunity to make their suggestions, tool making, assemble, conduct experiments… with a positive spirit, proactive, and creative. Besides that, the use of self-created experiments also helps students deepen their knowledge, and practice skills thereby contributing to fostering qualities and other competencies in teaching physics. In this paper, we propose the process of building and using self-created experiments, then proceed to self-create some experiments Chapter "Magnetism and electromagnetic induction" Physics 12 High School of Lao PDR and used in teaching to develop students' practical capacity.**

***Keywords*—capacity, practical capacity, self-created experiment, teaching physics**

I. Introduction

Physics is an experimental science. Therefore, most of the knowledge of physics is derived from observations, experiments, laws, models, and theories of physics. When drawn from a theoretical path it only becomes scientific knowledge when it is verified by experiment. Therefore, the use of experiments and the use of self-created 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 [1] has shown: "*From intuition to abstract thinking and from abstract thinking to practice is the way to perceive the truth, to perceive objective reality*". Therefore, 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. 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, Therefore, it is easy to promote the role of self-created experiments in teaching physics. Therefore, 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 helps 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.

"Education Strategy of the Lao Ministry of Education & Sports [2]" and the "Education Strategy of the Ministry of Education & Training of Vietnam [3]" 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. In many regions such as Asia and Oceania, DIY teaching and learning are carried out under the auspices of UNESCO in "Educational Innovation for Development Program" under the title "New trends in school science equipment" [4]. In Europe, especially in Germany, Völlmer and Möllmann [5] and Jodl and Eckert [6] have been interested in research self-created experiments. Wilke [7] and Nachtigall, Dieckűfer, and Peters [8] have researched self-created and used self-created experiments in teaching most of the parts such as: Mechanics,

Manuscript received October 20, 2022; revised November 4, 2022; accepted March 27, 2023.

Thermodynamics, Electricity, Optics… Most self-made experiments are made simply from cheap materials, easy to find: soft drink cans, water bottles... In Ref. [9], when learning about the situation of teachers in the use of physics experiments in some high schools have shown: The reason 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 recommended that teachers should experiment with simple, cheap and easy-to-find materials to use in teaching.

Thus, it can be said that the use of self-created experiments in teaching physics in high schools is really necessary, thereby contributing to the effective implementation of the 9th 5-year Education Strategy (2021–2025) of Lao PDR.

II. USING SELF-CREATED EXPERIMENTS IN TEACHING PHYSICS

Self-creation and use of self-created experiments in teaching physics towards the development of student's abilities have been and are very interesting in Vietnam reflected in the studies of the authors, such as Giao and Vinh [10], Duong [11], Dien [12], Anh [13]. In which the authors all argue that: to use self-created experiments in teaching physics effectively then it is necessary to build a self-created process and the process of using self-created experiments.

A. The Process of Self-Created Experiments

Through learning about self-created experiments and based on the research of other authors, we propose the process of self-created experiments according to the following steps:

Step 1: Study the objectives and contents of the lesson

Based on studying the objectives and contents of the lesson, to determine the knowledge units that need to be used in experiments to organize teaching…

Step 2: Find out the actual state of facilities and experimental equipment.

Finding out the actual state of facilities and equipment in the school's laboratory to indicate the level of satisfaction of the experimental needs for the lesson, thereby indicating which experiments are already available and which ones need to be self-created for use in teaching.

Step 3: Determination of Self-created experiment plan.

- Determine the purpose of the experiment: Answer the question of what purpose the experiment is used for, such as: What knowledge is formed, what skills are developed, or what specific competencies are contributed to the development of students.
- Proposing experimental plans: proposing some specific experimental plans.
- Selection of feasible plans: on the basis of the content lesson and condition actual facilities choose the most feasible experimental plan.

Step 4: Machining/manufacturing experimental equipment.

From the prepared materials, then proceeding to machine and manufacturing experimental instruments and being able to machine instruments experimental guaranteed on request, require students to have certain skills, must to learn about in-depth related physical phenomena and processes.

Step 5: Assemble, conduct experiments.

After machining and completing the necessary experimental equipment, the next step is to assemble the experiment according to the proposed plan and conduct the experiments to check the feasibility.

Step 6: Test and complete the experiments.

Through testing, detecting limitations, overcoming, and completing experiments to use in teaching.

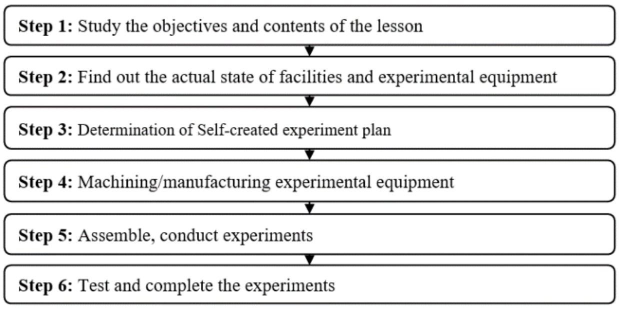

Figure 1. The process of self-created experiments.

B. Self-Created Experiments in Teaching Chapter "Magnetism and Electromagnetic Induction"

*1) **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 choosing the most feasible option to conduct self-created experiments (Figs. 2–4).

c) Prepare materials, experimental equipment

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

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 in Figs. 2–4.

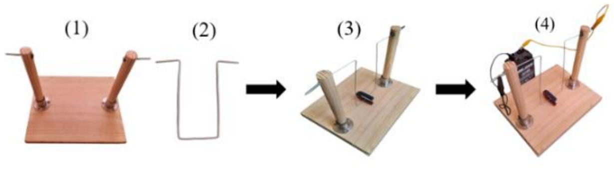

Figure 2. Self-created experiments about magnetic force acting on current in a uniform magnetic field.

f) Test and complete the equipment-set

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 Fig. 2(4).

Similarly, based on the above procedure, we have created some other experiments in Chapter "Magnetism and electromagnetic induction" Physics 12 including [14, 15]" (Fig. 3).

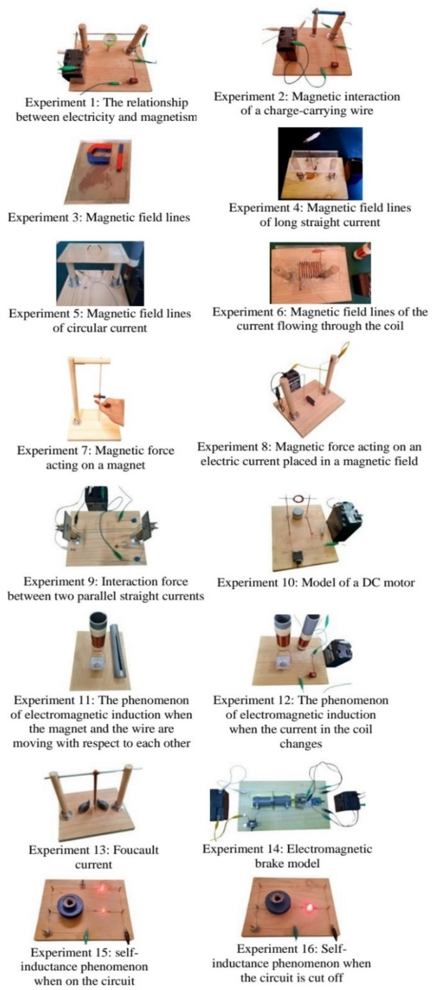

Figure 3. Self-created experiments to teach chapter "magnetism and electromagnetic induction".

C. The Process of Organising Teaching with the Use of Self-Created Experiments

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

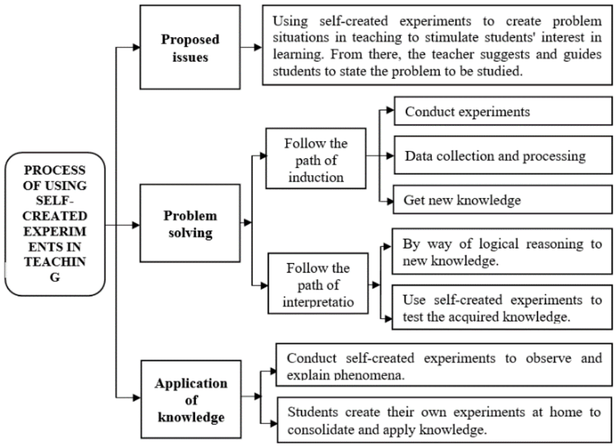

Figure 4. Teaching process with the support of self-created experiments.

The use of self-created experiments in teaching physics, it is necessary to master the following requirements:

- Clearly define self-created experiments 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 students, if the teacher conducts the experiments, before conducting it, it is necessary to introduce to the students: the purpose of the experiments, the steps to conduct the experiments and the task of the experiments. While the teacher conducts the experiments. If students conduct, it is necessary to introduce students to experimental tools, instructions on how to assemble, steps to conduct experiments, how to record, process results, and draw conclusions;
- Careful preparation of the experiments is required to ensure a successful experiment during class time.

Example: Using self-created experiments to raise problems.

Using self-created experiments is not only used in problem-solving, but also to stimulate learning interest, stimulate curiosity of students. Therefore, in this stage, in order to stimulate students' interest in learning, the use of self-created experiments to open the lesson must create unexpected surprises, contrary to the students' predictions. Then it will cause contradictions in students' perceptions and that are the most favourable conditions for teachers to suggest and guide students to raise issues in the contents.

For example, when teaching the lesson "*Magnetic force acts on electric current*", the following experiment can be used to propose a problem to be studied:

- Suggestion the tools
  (1) 01 Round wooden bar (Long 40 cm, Diameter 2 mm), 02 Round wooden bar (Long 30 cm and 12 cm, Diameter 2 cm),
  (2) 01 Pieces wood (20 cm × 25 cm × 2 cm), 02 Magnet.
- Assemble experimental set

Place magnet (2) on the base (1) so that they can rotate about the vertical axis Fig. 5(3).

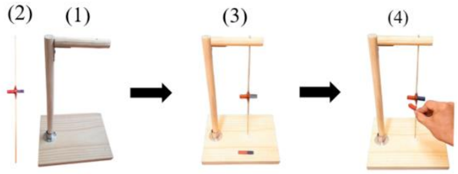

Figure 5. Experiments on magnetic interaction between 2 magnets.

- Experimental steps

Take turns bringing the same and opposite polarity magnets together, observe and comment.

- Conduct experiments and raise the problem

After introducing the experiments and the steps, the teacher raised the question: *When the same and opposite polarity magnets are brought together, what will happen*? Ask students to make predictions.

After students make predictions, the teacher conducts experiments, students observe and record the results.

From the experimental results, teacher suggests and guide students to state the problem from the contents:

"In the experiment, we see magnets interact with each other. So what is that force of interaction called? What features are there? How is it determined? Their applications in technology and life? Today's lesson and the following ones will help us solve those problems in turn."

III. Result and Discussion

A. *Contents of Evaluation in Pedagogical Experiments*

We conducted a pedagogical experiment in the samples 215 students from 6 classes at 3 high schools in Pakse City, Champasak Province. The selected experimental samples are equivalent, based on the survey of the test results at the beginning of the first semester and the average score of the students in physics.

In the pedagogical experiment, we collected data through interviews, through Rubrics, and observations of students' performance through behavioural indicators and tests. After statistics, synthesis, analysis, and data processes, we obtained the following results.

B. *Results of Pedagogical Experiments*

We have observed and monitored students' activities, thereby collecting and processing data to evaluate the development of students' practical ability in teaching physics in high schools with the use of use self-created the experiments.

1) *Qualitative assessment*

All lessons in experimental classes (using self-created experiments) are observed the lesson progress and students' learning activities, 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.

2) *Quantitative results*

We randomly selected a group of 8 students for each class to observe and evaluate the development of practical capacity during the experiments and the results are shown in the following Table I.

TABLE I. Results of Assessing the Practical Capacity of Students in the Pedagogical Experimental Class Using Self-Created Experiments

Activity	N	(X_i)									
		0		X < 5		5 ≤ X < 6.5		6.5 ≤ X < 8		X ≥ 8	
		n	%	n	%	n	%	N	%	n	%
1	24	0	0	5	20.8	17	70.8	2	8.3	0	0
2	24	0	0	4	16.6	16	66.6	4	16.6	0	0
3	24	0	0	4	16.6	14	58.3	6	25.0	0	0
4	24	0	0	3	12.5	12	50.0	8	33.3	1	4.1
5	24	0	0	3	12.5	10	41.6	9	37.5	2	8.3
6	24	0	0	3	12.5	9	37.5	10	41.1	2	8.3
7	24	0	0	2	8.3	8	33.3	11	45.8	3	12.5
8	24	0	0	1	4.1	6	25.0	12	50.0	5	20.8
9	24	0	0	1	4.1	5	20.8	13	54.1	5	20.8

The data (Table I) shows the number of students who achieved the score $6.5 \leq X < 8$ and $X \geq 8$ increased after each activity in the group teaching process (each activity uses a different self-created experiment and different lesson content). In the later activity, the number of students achieving good and good levels according to the criteria for assessing practical ability increased significantly.

In addition, we also assessed the student's academic performance through the test. Below is a statistical table to evaluate the learning results of students in the class using self-created experiments (Group B) with the class without using self-created experiments (Group A) and a table of statistical parameters (Table II).

TABLE II. STATISTICS OF STUDENTS' TEST SCORES

	N	Number of tests scored X_i										
		0	1	2	3	4	5	6	7	8	9	10
Group A	110	0	3	6	10	15	28	23	14	7	3	1
Group B	105	0	1	3	5	11	20	24	18	13	7	3

TABLE III. TABLE OF STATISTICAL PARAMETERS

	N	$\overline{X}$	$S.D$	$V(\%)$	$m = \frac{S.D}{N}$	$X = \overline{X} \pm m$
Group A	110	5.21	1.83	35.15	0.016	5.21 ± 0.016
Group B	105	6.02	1.86	30.98	0.017	6.02 ± 0.017

From the data in Tables II and III, indicate that the mean test score of Group B (using self-created experiments) is higher than Group A (without using self-created experiments), coefficient of variation of the group using self-created experiments is smaller than the group not using experiments, shows that the dispersion of numerical values when using self-created experiments is smaller, Therefore, the mean has high reliability. Thereby, it can initially be concluded that the use of self-created experiments in physics teaching has contributed to developing students' practical capacity and improving the quality of students' physics learning.

IV. CONCLUSION

Physics is an experimental science in which the use of experiments in general, in which, self-created experiments are indispensable and strongly necessary in teaching physics. The characteristics of self-created experiments, therefore, used in teaching physics in high schools not only aims to promote students' active awareness, but also contributes to the development of practical capacity for students to meet the requirements of program innovation in current general education. Therefore, it is necessary to strengthen and used of self-created experiments physics in high schools corresponding to the direction of developing students' capacity. The obtained research results show that the use of self-created experiments in teaching physics towards developing students' practical ability in high schools is feasible, in line with the current practice of educational innovation in the direction of developing student capacity in Lao PDR.

CONFLICT OF INTEREST

The authors declare no conflict of interest.

AUTHOR CONTRIBUTIONS

Bounnao Pathoumma conceived the study. Le Van Giao and Bounnao Pathoumma analyzed the data, conducted the research. Bounnao Pathoumma wrote the paper. Le Van Giao and Le Thi Minh Phuong revised the paper. All authors had approved the final version.

REFERENCES

[1] V. I. Lenin, *Lênin Full Episod*e, *Episode 29*, Philosopher's Pen, 1981.

[2] Ministry of Education and Sports, *Education and Sports Strategy 2020–2025*, 9th time, Vientiane, Lao PDR, 2020.

[3] Ministry of Education and Training, *Education Strategy 2011–2020 (issued together with Decision No: 711/QĐ-TTg*, date: 13/6/2012 of the Prime Minister, Hanoi, Vietnam, 2012.

[4] UNESCO, *New Trends in School Science Equipment*, Paris, 1980.

[5] M. Vollmer and K. P. Möllmann, "Low cost hands-on experiments for physics teaching," University of Applied Sciences, Germany, 2011.

[6] H. Jodl and B. Eckert, "Low-cost, high-tech experiments for educational physics," Universität Kaiserslautern, Germany, 1998.

[7] H. Wilke, *DIY Experiments in Physics*, Weinheim: WILEY-VCH Verlag GmbH & Co. KGaA, 2004.

[8] D. K. Nachtigall, J. Dieckhufer, and G. Peters, "Qualitative experiment with simple means," Uneversitot Dortmund, 1996.

[9] N. Hirca, "The influence of hands on physics experiments on scientific process skills according to prospective teachers experiences," Education Faculty, Bartin University, Turkey, 2013.

[10] L. V. Giao and N. T. A. Vinh, "Self-created research, exploitation and use of simple and cheap experiments in order to contribute to innovating methods of teaching physics in high schools towards positive cognitive activities of students," Ministerial-Level Scientific Project, Hue University of Education, 2006.

[11] H. T. Duong, "Research on the construction and use of experiments to improve students' cognitive activities in teaching Physics in junior high schools," Ph.D. dissertation, Hue University of Education, 2006.

[12] D. T. Dien, "Building and using simple tests in teaching Grade 6 mechanics in the direction of developing students' active, self-reliant and creative cognitive activities," Ph.D. dissertation, Vinh University, 2005.

[13] N. H. Anh, "Building and using self-created experiments in the direction of positive cognitive activities of students in teaching chapter: Mechanics, advanced 12th grade physics," Ph.D. dissertation, Hue University of Education, 2015.

[14] Ministry of Education and Sports, *Physics High School 12 Teacher's Book*, Educational Research Institute, Vientiane Capital, Lao PDR, 2016, pp. 92–113.

[15] Ministry of Education and Sports, *Physics High School 12 Book*, Educational Research Institute, Vientiane Capital, Lao PDR, 2016, pp. 99–129.