Experimental Teaching by Scientific Methods for Developing Students' Natural Finding Capacity in Teaching Natural Science in Vietnamese High Schools

Pham Thi Hong Tu[1], Nguyen Thi Hang[1], Luong Thi Thuy Van[1], Ha Van Dung[2,*], Nguyen Thi Hang Nga[3] & Cao Xuan Phan[4]

[1]Thai Nguyen University of Education, Vietnam

[2]Vietnam Journal of Education, Vietnam

[3]Hanoi National University of Education, Vietnam

[4]Bien Hoa High School for the Gifted, Ha Nam Province, Vietnam

*Corresponding author: Vietnam Journal of Education, Vietnam. E-mail: hvdung.tcgd@moet.edu.vn

Received: October 26, 2022 Accepted: December 1, 2022 Online Published: December 12, 2022

doi:10.5430/wje.v12n6p1 URL: https://doi.org/10.5430/wje.v12n6p1

Abstract

Natural science itself is an experimental science, so practice and experimentation are important and are typical teaching methods of this subject. To make practice and experiment play the highest strengths in teaching and developing the ability to learn about nature - one of the three specific competencies of natural science, the association of experiments with scientific methods plays a special role. This article presents the general problems of teaching practical experiments according to the scientific method and applying it in teaching the topic "Living animals" in Natural Science, grade 7. The research results can be teachers' references in teaching Natural Science to meet the teaching objectives in the direction of developing students' capacity in Vietnam in the current period.

Keywords: scientific method, practice, experiment, natural science

1. Introduction

In the 2018 general education curriculum, Natural Science is a new and compulsory subject taught in lower secondary schools. This subject helps students continue to develop the qualities and competencies that have been formed and developed at the primary school level (Vietnam Ministry of Education and Training, 2018). Among the competencies that need to be formed and developed for students in teaching Natural Science, there is the ability to learn about nature. This capacity includes the following criteria: proposing problems, asking questions to problems; making judgments and formulating hypotheses; planning and implementing the hypothesis testing plan; writing, presenting reports and discussing, making decisions and making suggestions (Vietnam Ministry of Education and Training, 2018).

There are many methods to develop the ability to practice experiments for students, in which practice and experiments are typical teaching methods of this subject and have an important role and meaning. However, in reality, most teachers use practice and experiments as an activity to consolidate knowledge and practice skills, which focuses on students performing experimental manipulations according to the available templates. Therefore, in order to exploit the strengths of practice and experiment in developing the components of natural inquiry ability for students, it makes sense to attach experiments according to the process of scientific methods. In this study, we research and propose the process of teaching practical experiments according to the scientific method suitable for junior high school students and apply the process in teaching the topic "Living animals" of the Natural Science grade 7.

2. Method

2.1 Theoretical Research Methods

To conduct the research, the researchers selected, collected and analyzed, synthesized documents on the ability to learn about nature, and teach practical experiments according to scientific methods. This method helped to clarify the basis and advantages of teaching practice experiments in scientific methods with the development of natural inquiry capacity on that basis, to propose appropriate procedures in teaching natural sciences. in junior high school.

2.2 Experimental Method of Pedagogy

The researchers initially verified the influence as well as the feasibility of applying the experimental teaching process according to the scientific method with the development of the ability to learn about nature in teaching 6 experiments on the topic "Living animals", Natural Science 7. Designed and organized student learning activities according to strict procedures.

2.3 Methods of Mathematical Statistics

The researchers used mathematical statistical methods to process experimental results data to have authentic comments and assessments.

3. Result and Discussion

3.1 Develop the Ability to Learn Nature

3.1.1 Natural Ability to Learn

"Capacity" is an individual attribute formed and developed by inherent qualities and the process of learning and training, allowing people to synthesize knowledge, skills and other personal attributes. such as excitement, belief, will, ... successfully performing a certain type of activity, achieving desired results in specific conditions (Vietnam Ministry of Education and Training, 2018).

"Capability to learn about nature" is the ability to perform some basic skills to understand and explain things and phenomena in nature and life; demonstrate problems in practice with scientific evidence. The ability to learn naturally includes the following criteria: proposing problems, asking questions about problems; making judgments and formulating hypotheses; planning and implementing the hypothesis testing plan; writing, presenting reports and discussing, making decisions and propose opinions (Vietnam Ministry of Education and Training, 2018).

3.1.2 Developing the Ability to Learn about Nature

According to the Vietnamese Dictionary, development is a change or change in the direction of increasing, from less to more, narrow to wide, low to high, and simple to complex (Hoang et al., 2008). It can be seen that development is the process of moving in the upward direction of things, from a low level to a high level. Capacity development is the process of changing for the better of a person in terms of knowledge, skills, attitudes and effectiveness of his actions in a given context. Developing the ability to learn about nature is the process of creating a certain change (increasing in quality) of a type of activity based on the relationship between professional knowledge and skills (expressed in element) of natural inquiry (such as problem-finding, hypothesizing, finding and performing hypothesis proofs, drawing conclusions) and with the researcher's qualities (such as initiative, creative, hardworking, honest,…). Thus, it can be seen that developing the capacity to learn about nature is to develop the components of this capacity in each person, which manifests in his or her ability in the field of natural research or inquiry.

3.2 Practice Experiments according to the Scientific Method

3.2.1 Experimental Practice

"Experiment" is a research method, characterized by the experimenter actively changing and systematically recording at least one independent variable whose active change has an effect on the dependent variable and the removal of the effect of other variables to confirm the correctness of a hypothesis or disprove it (Meier & Nguyen, 2016). In teaching, an experiment is used as a teaching method. Through experiments, learners discover and acquire scientific knowledge, and develop research capacity and experimental skills. "Practice" means "to do to put theory into practice or to make it true by concrete deeds or actions; follow a certain sequence and rules" (Hoang et al., 2008). "Experimental practice" is understood as conducting experiments in practical activities performed by students so that students understand the purpose of experiments and experimental conditions. Through practice and experiments, students identify the nature of process phenomena (Dinh & Nguyen, 2006). There are many types of experiments,

each type of experiment has certain roles in teaching. In which, in order to develop the components of the ability to learn about nature for students, it is necessary to use the research-oriented experimental method or use the experiment according to the steps of the scientific method (Meier & Nguyen, 2016).

3.2.2 Scientific Method

According to the Oxford dictionary, "The scientific method has been the gold standard for investigating the natural world. It is how scientists correctly arrive at new knowledge, and update their previous knowledge. It consists of systematic observation, measurement, experiment, and the formulation of questions or hypotheses" (https://dictionary.cambridge.org/en/dictionary/english/oxford). The scientific method encourages students to have scientific habits such as observing and discovering problems; Hypothesizing and finding ways to prove the hypothesis; Designing and conducting experiments, gathering evidence, and applying concepts learned. Most of them require skills such as designing an experiment, working in groups, solving problems, interpreting data, writing reports, presenting reports and reading primary documents (Coil et al. ., 2010). Based on studies showing that organizing teaching by scientific method has the effect of attracting students to actively solve problems and develop critical thinking, as well as improve their academic achievement (Prince & Felder, 2007). Several other studies have shown that the acquisition of these skills is a hallmark of a university science education (Gormally et al., 2009; Coil et al., 2010) so to organize practice Experimenting by scientific method with secondary school students should have very specific orientations and instructions to ensure fit and reasonableness.

3.2.3 Developing Students' Ability to Learn About Nature by Experimenting with Scientific Methods

The practice of experiments according to the scientific method is suitable for the development of the capacity to learn about nature. In which, students will be able to stand in the position of researchers, experience the basic skills of researchers such as: observation and discovery of research problems; making a hypothesis and finding a way to prove it by scientific experiment - This is the most convincing way to prove a scientific hypothesis; designing and conducting experiments to prove hypotheses, drawing conclusions and presenting and report research results; explaining, critique, and defending research results (Harker, 1999). These experiences are manifestations of the ability to learn about nature, thereby meeting the requirements of reforming general education in Vietnam in the current period. Teaching practice, experimenting by scientific method is one of the measures to stimulate students' initiative, creativity and independent thinking ability. Using the scientific method with successful experiments will help teachers achieve the lesson objectives set out optimally and regularly and reasonably, will facilitate the development of learners' capacity. respectively (D'Costa & Schlueter, 2013).

There are a number of authors who have researched on experimental teaching to develop the ability to understand the living world, in the direction of developing scientific research capacity in teaching Biology such as Dang and Tran (2017), Dang and Nguyen (2020). Specifically, Pham et al. (2020, 2021) have studied the experimental teaching to develop biological competence in general and develop students' ability to learn about the living world in teaching biology.

Thus, whether studying experimental practice in the direction of developing scientific research capacity or in the direction of teaching problem solving or approaching scientific thinking, teaching and practicing experimentation is an invaluable step. equally important in the scientific research process. In which, as soon as the hypothesis is given, the teacher organizes for students to propose a way to prove the hypothesis. Students must provide possible solutions to the task with suggested steps and strategies. Students then have to self-assess the solution and decide which solution is more applicable, provide an explanation, and perform an experiment by design that is easiest to implement (Cheng et al., 2017), and in all solutions, experimentation is the most meaningful way to prove the hypothesis most clearly (DeBoer, 2019).

3.3 The Process of Teaching and Experimenting with Scientific Methods to Develop Students' Ability to Learn about Nature

3.3.1 Teaching Principles of Experimental Practice According to Scientific Methods to Develop Students' Ability to Learn about Nature

Based on the important teaching principles of Treffers (1991), we determined the use of experiments in the direction of developing students' ability to learn about the living world in teaching the natural science subject to practice according to the following main principles: (1) The principle of ensuring the requirements to be met according to the regulations of the Ministry of Education and Training (minimum requirements principle); (2) Activity principle: In teaching, learners are active subjects participating in the teaching process, their activities are the decisive factor in the effectiveness of the teaching and development process. capacity. "What action - that capacity" Or "Capacity is

formed from activities and through activities, capacity can be formed and developed" (Weinert, 2001). Therefore, in order to develop the ability to learn about nature in students, teachers must design and involve students in activities corresponding to the criteria and manifestations of natural inquiry ability; (3) the interaction principle; (4) The suitable principle.

3.3.2 The Process of Teaching and Experimenting with Scientific Methods to Develop Students' Ability to Learn about Nature

Based on experimental steps in the direction of Meier and Nguyen (2016); Based on the steps of the scientific research method of Gower (2012); Bradford and Hamer (2022); The process of teaching and developing capacity by author Le and Phan (2016); Based on the expression criteria of the ability to learn about nature (Vietnam Ministry of Education and Training, 2018b), we define a scientific method of hands-on experimental teaching in order to develop the ability to learn about nature. However, in students, there are 3 stages as shown in Figure 1:

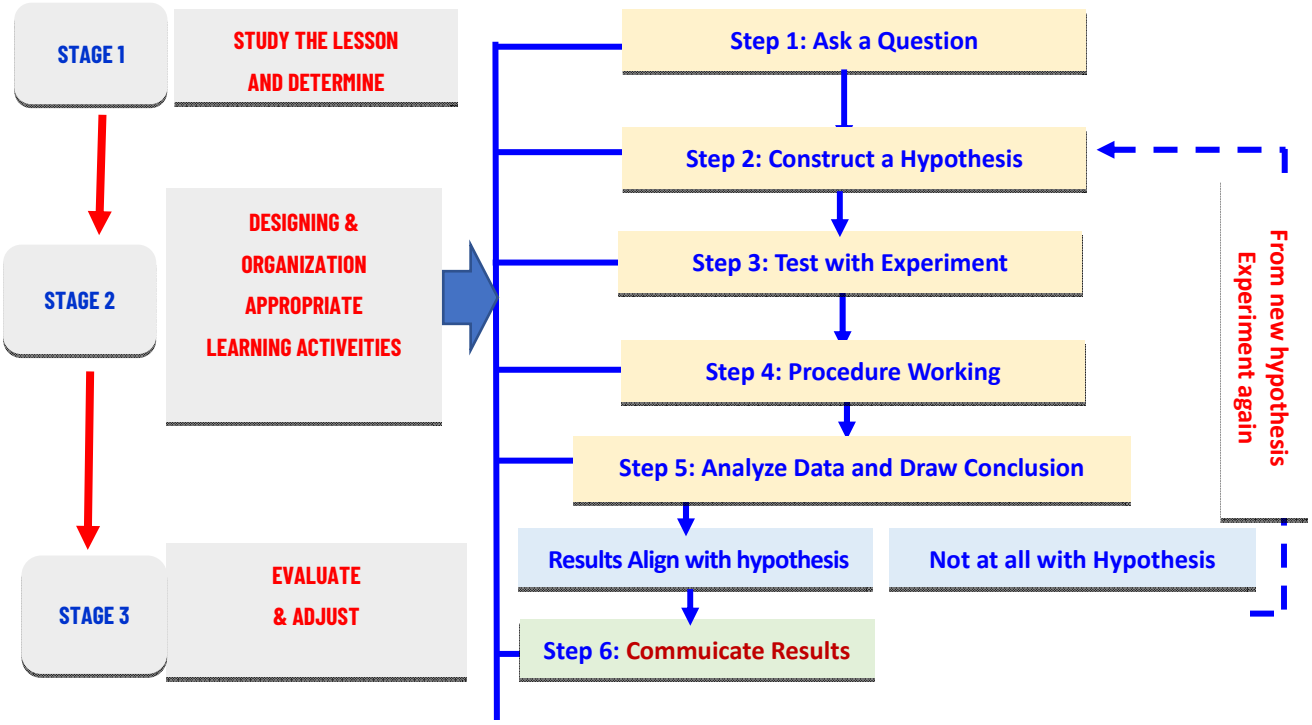

Figure 1. The Process of Teaching and Experimenting with Scientific Methods to Develop Students' Ability to Learn about Nature

Applying the process in teaching and practicing experiment "Metabolism and energy metabolism in organisms" (theme "Living things" - Natural Science 7): We organize for students to experience the process 6 steps of a scientist with 6 experiments in 2 months. Experiments include (1) Experiments to demonstrate that photosynthetic plants release oxygen; (2) Experiments prove that photosynthetic plants produce starch; (3) Experiments demonstrate that respiration releases heat; (4) Experiments demonstrate that respiration absorbs oxygen and releases carbon dioxide; (5) Experiment to prove that the body transports water; (6) Experiments demonstrate that leaves transpire.

Example: Applying the process in teaching practice experiments to demonstrate photosynthesis in green plants (theme "Living animals" - Natural Science 7).

Phase 1: Determining the objective of the experiment: From the requirements of the Natural Science program (2018), "Experiment to demonstrate photosynthesis in green plants" was determined to determine the goal of energy development. natural research force: (1) Asking research questions, (2) Forming hypotheses; (3) Proposing a plan to prove the hypothesis (Experiment layout); (4) Conducting experiments; (5) Analyzing results and drawing conclusions; (6) Reporting the results.

Stage 2: Design and organize learning activities: Put students into learning activities in the direction of scientific

research with 2 experiments, that is: an experiment proving that photosynthesis in green plants forms crystals. Powder and experiments demonstrate that photosynthetic plants release oxygen. In order to facilitate the grade 7 students, teachers need to have timely guidance and support for students. Specifically, with the steps in the experiment that proves that photosynthesis green plants release oxygen, teachers can suggest and model a number of steps: modeling questions, modeling hypotheses; suggesting the remaining steps. To the experiment to prove that photosynthesis produces starch, the independence and autonomy of students gradually increased. Activities and suggestions are shown in Table 1.

Table 1. Students' Activities according to Scientific Method Steps

Step	Students' activities	Teacher's suggestions
1. Ask a research question	Students can ask questions: (1) What are the products produced by photosynthesis when there is light? (2) How is it possible to prove whether or not starch or oxygen is produced from leaves in the presence of light?	Suggest research questions if students have difficulty; Determine whether to test starch or not with iodine reagent and test whether oxygen is released or not with a fire stick
2. Identify the hypothesis	Students hypothesized: (1) If the leaves are illuminated, starch will be produced and vice versa; (2) There is a release of oxygen in the leaves of plants when exposed to light	Hints for students to make well-founded guesses about the expected outcome and validate the problem given to be tested.
3. Test the hypothesis by experiment	Assign members to prepare samples for testing with or without illumination; Study the textbook to determine the steps to conduct the experiment	Teacher orientation to support students
4. Conduct experiments	Carry out the experiment according to the defined steps; Record the results and explain the experimental steps	
5. Analyze the results and draw conclusions	- Compare the results with the hypothesis to confirm or disprove the hypothesis - Conclusion: When there is light, the leaves of plants produce starch and release oxygen	
6. Report the results	Write reports, present reports	

Stage 3. Evaluation and adjustment: After organizing experimental teaching according to the scientific process to develop students' ability to learn about nature, teachers base on the actual situation of teaching to detect obstacles in the process of organizing according to the plan to adjust activities in a timely manner. The assessment focuses on assessing the students' ability to develop the elements of natural inquiry through learning products in the process of performing practical experiments and evaluating by case exercises. After learning the topics. The results of the student assessment are presented in section 3.4.

3.4 Pedagogical Experience

To evaluate the development of students' natural inquiry ability, we used the evaluation form of 35 groups of students, each group of 6-7 students from four secondary schools in the area in Thai Nguyen province. The evaluation sheet includes 6 criteria of natural inquiry capacity with 3 levels: Level 3 (the highest level) is the self-help groups that can perform the task correctly without the help of teachers; Level 2 points are groups that can do as required but need the teacher's advice; Level 01 point is the group that can do it but is still confused and needs a lot of help from the teacher. Statistical results of 6 criteria of student groups are shown in Table 2, in which criteria from 1 to 6 are: 1. Asking research questions, 2. Hypothesis building, 3. Design get the experimental plan to test the hypothesis, 4. Implement the selected experimental plan, 5. Analyze the results and draw conclusions, 6. Report the results.

From Table 2, it can be seen that the mean score of the criteria for assessing the ability to learn about nature after the experiment (2.49) is higher than before the experiment (1.9), the difference in mean value is 0.52 showing that the Using experiments according to scientific methods has had a great impact on the development of students' ability to

learn about nature.

Table 2. Statistical Scores to Evaluate the Development of 6 Criteria of Natural Inquiry Capacity before and after the Experiment

Criteria	Before the experiment (BTE)				After the experiment (ATE)			
	Number of groups that scored points			Mean	Number of groups that scored points			Mean
	1,0	2,0	3,0		1,0	2,0	3,0	
1	11	22	2	1.74	2	20	13	2.31
2	13	20	3	1.69	2	20	13	2.31
3	8	23	4	1.91	1	23	11	2.29
4	6	22	7	2.03	0	19	16	2.47
5	8	22	5	1.91	0	15	20	2.57
6	7	18	10	2.09	0	16	19	2.54
	Average score of experimental ability before experiment =1.9				Average score of experimental ability after experiment = 2.42			
	Average point difference = 0.52							

To compare the level of progress on each criterion of the ability to learn about nature, from Table 2, we make a comparison chart shown in Figure 2.

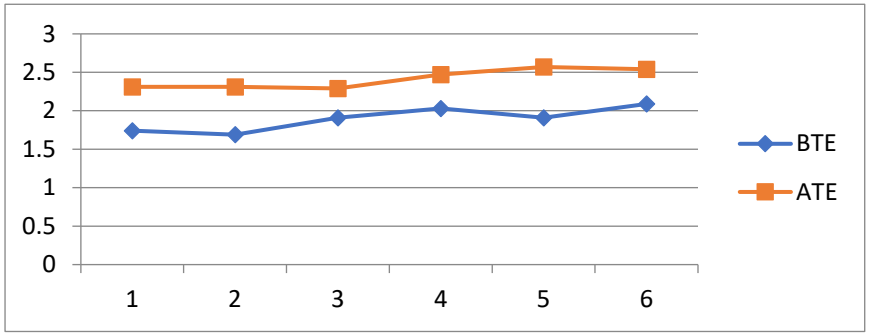

Figure 2. A Graph to Evaluate the Progress of Each Criterion under the Natural Learning Ability of the Experimental Class

From the chart we can see that there is an improvement in the natural ability of the experimental class during the learning and training process. The graph of each criterion after the experiment is higher than before the experiment. The above results have shown that: Teaching using experiments according to scientific methods makes an important contribution to the development of students' ability to learn about nature.

To confirm that the difference (increase) of each criterion at the post-experimental test compared with the pre-test is not random and significant, we analyze the results by comparing values mean and analysis of variance. The results are shown in Table 3.

Table 3. X-test and Analysis of Variance of Experimental Results

Criteria	Mean		$\bar{X}$ test and analysis of variance			
			Known Variance		Z=U	FA
	BTE	ATE	BTE	ATE		
1	1.74	2.31	0.33	0.31	-4.2	17.5
2	1.69	2.31	0.39	0.33	-4.32	15.62
3	1.91	2.29	0.43	0.27	-2.62	6.87
4	2.03	2.47	0.37	0.26	-3.36	11.34
5	1.91	2.57	0.37	0.25	-4.79	16.11
6	2.09	2.54	0.49	0.26	-2.99	9.78

To determine "There is no difference between the results of competency development before and after the experiment", using the U criterion to test the hypothesis H0 and the alternative H1. The test results shown in Table 3 show that $\overline{X}$ of each criterion in the post-experiment evaluation is larger than $\overline{X}$ of each corresponding criterion in the previous experiment (Example in criterion 1: $\overline{X}$ATE). = 2.31> $\overline{X}$BTE = 1.74); the variance of each criterion in the post-experiment evaluation is smaller than the pre-experimental evaluation (Example: In criterion 1: ATE variance is 0.31 < BTE variance = 0.33). Thus, the evaluation score in the next experiment was higher and more focused than the previous time. The absolute value of U of each criterion is greater than the standard z-value (for example, in criterion 1 the absolute value of U=4.2 > 1.96 -standard z-value), with a probability of 1.64 > 0.05 Therefore, hypothesis H0 should be rejected and hypothesis H1 accepted. That is, there is a difference in the results of capacity assessment before - after the experiment and this difference is statistically significant.

Continue with the analysis of variance. The results in Table 3 show that the FA value in each criterion is larger than the F-crit value (standard). These values show that the above experimental results have a great influence and the difference in natural learning ability in groups of students at the time of assessment before and after the experiment is not random.

Thus, the results of the above assessment have proved that: The use of experimental practice according to the scientific method in teaching the topic "Living animals" (Natural Science 7) has great significance in teaching and learning. the development of natural inquiry capacity in students and this difference is statistically significant.

4. Conclusion

In order to develop the student's ability to create experiments, the use of experimental practice according to the scientific method has an important meaning in teaching natural science in junior high schools. On the basis of determining the goal of teaching and experimenting according to the subject program of the Ministry of Education and Training, teachers design and organize students' learning activities according to the steps (skills) and the rigorously scientific method. Thereby, students experience the manipulation of scientists such as asking research questions, making hypotheses, proposing experimental plans, performing experiments to test hypotheses; collecting evidence, analyzing, processing to draw conclusions and evaluating the results obtained. Through these experiences, students' self-study ability is increasingly developed. The results of applying the process in teaching the topic "Living animals" Natural Science 7 initially show that the use of experimental practice according to the scientific method is feasible and meaningful. However, in order to have firmer conclusions, further studies are still needed on a larger number of students as well as assessing the change in the ability of each individual student.

Acknowledgements

The authors would like to thank the support of the Grassroots Project, code TNUE-2022-10.

References

Bernd, M., & Nguyen, V. C. (2016). *Modern teaching theory: The basis of innovation in teaching objectives, content and methods*. Hanoi, Vietnam: Pedagogical University Publishing House.

Bradford, A., & Hamer, A. (2022). *Science and the scientific method: Definitions and examples*. Published January 17, 2022. Retrieved from https://www.livescience.com/20896-science-scientific-method.html

Cheng, S. C., She, H. C., & Huang, L. Y. (2017). The impact of problem-solving instruction on middle school students' physical science learning: Interplays of knowledge, reasoning, and problem solving. *Eurasia Journal of Mathematics, Science and Technology Education*, *14*(3), 731-743. https://doi.org/10.12973/ejmste/80902

Coil, D., Wenderoth, M. P., Cunningham, M., & Dirks, C. (2010). Teaching the process of science: faculty perceptions and an effective methodology. *CBE-Life Sciences Education*, *9*(4), 524-535. https://doi.org/10.1187/cbe.10-01-0005

D'Costa, A. R., & Schlueter, M. A. (2013). Scaffolded instruction improves student understanding of the scientific method & experimental design. *The American Biology Teacher*, *75*(1), 18-28. https://doi.org/10.1525/abt.2013.75.1.6

Dang, T. D. T., & Nguyen, T. D. P. (2020). Organizing experimental and practical activitiestowards developing students'competency in teaching "Body Biology" module at high school. *Vietnam Journal of Education, 480*,

25-30.

Dang, T. D. T., & Tran, V. B. (2017). Designing experimental and practical activities towards developing scientific research competence for students in teaching module Biology Body (Biology 11). *Vietnam Journal of Education, 418*, 42-45.

DeBoer, G. (2019). *A history of ideas in science education*. Teachers college press.

Dinh, Q. B., & Nguyen, D. T. (2006). *Theory of teaching Biology - General part*. Vietnam Education Publishing House.

Gormally, C., Brickman, P., Hallar, B., & Armstrong, N. (2009). Effects of inquiry-based learning on students' science literacy skills and confidence. *International journal for the scholarship of teaching and learning*, *3*(2), n2. https://doi.org/10.20429/ijsotl.2009.030216

Gower, B. (2012). *Scientific method: A historical and philosophical introduction*. Routledge.

Harker, A. R. (1999). Full application of the scientific method in an undergraduate teaching laboratory. *Journal of College Science Teaching*, *29*(2), 97.

Hoang, P. (editor), Vu, X. L., Hoang, T. T. L., Pham, T. T., Dao, T. M. T., & Dang, T. H. (2008). *Vietnamese Dictionary*. Da Nang Publishing House.

Le, D. T., & Phan, T. T. H. (2016). *Teaching in the direction of forming and developing learners' competencies in high schools*. Pedagogical University Publishing House.

Pham, T. H. T., Dang, T. T. H., & Hoang, A. T. (2020). Teaching experimental practices to develop biological competence for students at high schools. *Vietnam Journal of Education, 483*, 38-43.

Pham, T. H. T., Nguyen, T. H., & Nguyen, T. H. (2021). Using experiments connected with practical problems to develop students' competence to understand the living world in teaching "Metabolically and energy transformation in plants" (Biology 11). *Vietnam Journal of Education, 514*, 12-16.

Prince, M., & Felder, R. (2007). The many faces of inductive teaching and learning. *Journal of college science teaching*, *36*(5), 14-20.

Treffers, A. (1991). *Realistic mathematics education in primary school: On the opening of the Freudenthal Institute*. Utrecht: CD-Beta.

Vietnam Ministry of Education and Training. (2018). *Circular No. 32/2018/BGDDT dated December 28, 2018 on the promulgation of the new general education program*. Retrieved from https://moet.gov.vn/van-ban/vanban/Pages/chi-tiet-van-ban.aspx?ItemID=1301

Weinert, F. E. (2001). Concept of competence: a conceptual clarification. In D. S. Rychen, & L. H. Salganik (Eds.), *Defining and selecting key competencies* (pp. 45-66). OECD.