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Article

Developing Experiment Skills for Pre-service Teachers of Biology in Vietnam

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Abstract

There has been a growing demand for teacher training institutions to equip pre-service teachers with practical skills that can enhance their teaching performance. In Biology teacher education, experiments have been employed with the educational approach to compensate for inadequate classroom-only instruction. This study aimed to assess the effectiveness of an intervention using biological experiments in developing experiment skills of pre-service teachers of Biology in Vietnam. The study also aimed to identify the challenges to the acquisition of experiment skills faced by Vietnamese pre-service teachers. A group of 128 pre-service teachers from four teacher-training institutions participated in the experimental courses. Pre-service teachers' improvement in terms of knowledge of the subject matter and experiment skills throughout the experimental courses was evaluated using pre-tests, progress tests, post-tests, and observations. The results showed significant improvements in the performance of pre-service teachers as they were provided with an increasing amount of experiment practices. This indicated the effectiveness of training pre-service teachers to acquire experiment skills for their future teaching practices and supported the need to incorporate experiment training in teacher education curricula. Meanwhile, interviews with teacher trainers and pre-service teachers after the experimental courses revealed four major obstacles to the acquisition of experiment skills, namely school, curriculum, teacher trainer and pre-service teacher factors.

Keywords

Teacher training institutions, experiments, experiment skills, pre-service teachers, Biology education

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Equipping students with 21st-century skills such as collaboration, communication, creativity, and critical thinking has been among the top agenda of higher education institutions around the world. Introducing experiments and upgrading laboratory facilities have become one educational approach used by higher education institutions to guarantee a labor force facilitated with those skills to meet the needs of society (Atav & Altunoglu, 2009; Gobaw & Atagana, 2016; Nowrouzian & Farewell, 2013). The effectiveness of experiments is well acknowledged in science education. Many studies (for example, Düppers, 1975; Eckes & Wilde, 2019; Odubunmi & Balogun, 1991; Rizki et al., 2018; Stawiński, 1986) have found that teaching and training delivered by means of laboratory experiments yield more successful outcomes both cognitively and affectively. This is because experiments allow science to be approached from the student's eyes through observing, exploring, questioning, researching, hypothesizing, and interpreting phenomena (Düppers, 1975; Eckes & Wilde, 2019; Odubunmi & Balogun, 1991). Experiments have also been found to assist students in concretizing theoretical knowledge and contribute to the acquisition of skills required in the 21st century.

With the recent strong emphasis on the use of experiments in education, the aims of this study were two-fold. Firstly, it aimed to identify and develop a procedure for using experiments in Biology teacher training courses to cultivate and improve experiment skills for pre-service Biology teachers. Secondly, it aimed to examine the implementation of the procedure to assess its currency and feasibility. The reason to select the research participants to be pre-service teachers at teacher education colleges was motivated by recent international literature that highlights the increasingly important role of science teachers in promoting students' career awareness for example (Cohen & Patterson, 2013). Experiment skills are integral to effective Biology education and need to be developed in pre-service teachers of Biology before they can practice teaching. Wenglinsky (2000) finds that students trained by teachers competent in laboratory-related skills are more competent than the students trained by teachers who do not have such skills. In other words, knowledge and skill development in teaching Biology depends crucially on the mastery of experiment skills and knowledge of pre-service teachers during their initial preparation for teaching practice at teacher training institutions. In the context of Vietnam, every secondary school student is exposed to at least one science teacher, including a Biology teacher, which makes it necessary to properly train pre-service teachers with the skills they need to effectively perform their future teaching (Ho et al., 2018).

This paper is structured in four main parts. The literature review summarizes existing knowledge regarding the use of experiments as an educational approach as well as the benefits and the consequences involved. The literature review also provides an overview of Biology education and Biology teacher education in Vietnam to set the context for the study. The paper then outlines the methodology used, including the research sites, the sampling, the research design, and the data collection and the analysis process. The quantitative and qualitative data from the study were then presented, followed by a discussion on the effectiveness and the challenges in using experiments in Biology teacher education courses in Vietnam.

Literature Review

Experiments with Educational Approach in Biology Education

Biology is considered a key discipline in understanding and responding to several pressing issues in modern society, from population growth, human impacts on ecosystems and services to climate change and sustainability (Kim & Diong, 2012). Biological knowledge is intrinsically related to building a sustainable relationship between nature and human society; thus, its role is essential in responses to issues and changes in life and the world in the twenty-first century.

As a science, Biology is known to have the following characteristics (Allen & Baker, 2017):

a) It is based on empirical knowledge, which is commonly obtained through senses.
b) It is characterized by a commitment to rationality, which cannot be accomplished without using rational methods to seek explanations of biological phenomena.
c) It is subject to repeatability, meaning a procedure being repeated in multiple investigations.
d) It is subject to testability as testable ideas provide a basis for further questions and research.
e) It allows generalization to be made about all organisms rather than just individual organisms.

It can be highlighted from the characteristics above that Biology as a science or as a science subject lends itself naturally well to experimentation or is committed to the use of experimentation. Experiments in Biology refer to interventions in a natural process so that the effects of the interventions can be observed (Allen & Baker, 2017). Experiments in Biology education refer to a range of practical experiment activities that engage and assess students' performance of practical tasks in planned interventions (Hacking, 1983). Curricular reforms since the 1960s and early 1970s in the Western world have sparked interest in experiment-oriented Biology teaching under the influence of the learning-by-doing movement. In recent years, Biology education has increasingly involved laboratories and outdoor venues since instruction delivered only in the classroom has been deemed inadequate (Moore, 2003).

Extensive research conducted into the methodology, aims and functions of experiments in Biology education has proven their integral role in equipping students with important skills and competencies. First and foremost, experiments in Biology education are acknowledged as being able to associate students' current knowledge with their newly learned information, to provide an insight into the connections and transitions between concepts, and enhance students' cognitive capacity (Allen & Baker, 2017; Gagné & White, 1978). This is since a process of conducting a biological experiment necessarily involves the activity of observing a phenomenon, hypothesizing plausible explanations, predicting outcomes, controlling variables, graphing biological evidence collected, interpreting, and inferring results, and communicating results. Second, the use of experiments in Biology education has been found to make student-centered objectives more feasible since students can take their initiative in learning by doing. Knowledge, especially applicable to solving the issues in students' daily life, can be internalized (Sayan & Mertoglu, 2020). Third, experiments are known to provoke curiosity beyond the technicalities of laboratory apparatus regardless of scopes of experiments or places to perform them. It has been stated that the exotic atmosphere of the laboratory, the smell of chemicals in the environment, and the presence of experimental tools or samples in some laboratories can motivate students and stimulate their creativity and discovery skills (Bahar, 2016). Overall, the use of experimentation in Biology education reflects a constructivist paradigm in which students are given the opportunities to actively construct their understanding of scientific phenomena.

To cultivate experiment skills for Biology students, several approaches have been utilized, the two most common of which are expository instruction and inquiry instruction (Johnson & Lawson, 1998). The former involves providing extensive instruction for students to achieve the results of an experiment; this approach, however, does not aim to gain a deep understanding of experimental design. The latter, on the other hand, involves more active learning that helps learners develop the knowledge and understanding of scientific ideas, as well as an understanding of how scientists study the natural world. Recommendations over the past two decades have emphasized the need to shift from expository to inquiry-based laboratories in which students are given more freedom in defining the experiment procedures and analyzing data (Luckie et al., 2004; Park Rogers & Abell, 2008).

In their study involving scientists and teachers, Azevedo (2004) argues that the manipulation or observation during experiments is not sufficient; instead, developing experiment skills must also involve developing characteristics of scientific work. This means that students must reflect, discuss, explain, report on the phenomena that they observe which will give their work the characteristics of a scientific inquiry. From this perspective, students are not limited to the simple execution of a previously established script but can begin to reflect on the whole process, report and argue about their observations actively by proposing possibilities for resolution of a problematic situation. In addition to these aspects, Brownell and Kloser (2015) suggest developing attitudinal content during these activities since it is possible to encourage the valuation of collective work, for example, by showing the importance of listening and hearing, sharing ideas and making decisions together. With this, according to Zômpero and Laburú (2011), students can improve their cognitive abilities and familiarize themselves with such procedures as hypothesizing, annotating, analyzing data, valuing, or critiquing.

Teachers of Biology assume great responsibilities in delivering effective Biology teaching with the embedment of experiments (Gonçalves & Marques, 2013; Kang & Wallace, 2005). Despite the increasing awareness among science teachers about the indispensable role of laboratory work and experiments in teaching Biology, the reality is that teachers have not allocated an adequate amount of their instruction to experiments. Findings by Atav and Altunoglu (2009) on 150 pre-service teachers of Biology reveal that 90% of the teachers surveyed are fully aware of the integral role of experiments in Biology classes, yet only 65% are confident in using experiments in their Biology class. The major reasons behind this situation are the lack of experiment skills among teachers and the lack of equipment in laboratories. Findings by Degirmenci and Dogru (2019) and Ocak et al. (2005) further indicate that even when schools have sufficient experiment equipment, Biology teachers tend to prefer traditional practices with textbooks to the computer, the Internet, and the laboratory. Teacher training institutions have also been found to be inadequately preparing pre-service teachers for experiment skills and thus a deep understanding of the subject matter (Atav & Altunoglu, 2009). This leads to the argument that training allows pre-service teachers to invest their time and effort in sharpening their experiment skills and make good preparation for their future teaching (Sülün et al., 2004).

Biology Education in Vietnam

What Vietnam has achieved for its education system can be considered remarkable for a developing country. Vietnamese students' performance in the Program for International Student Assessment (PISA) science subjects has been comparable to that of students from many established education systems such as Canada, Finland, or the Republic of Korea (OCED, 2015). Educational reform initiatives in the country have always stressed the need to innovate teaching and learning practices radically and comprehensively across all the school levels. The new general education curriculum launched in 2018 for the school sector particularly articulated its aims to "increase practice and application of knowledge to real-life" and enhance experiential learning to build students' competency (Ministry of Education and Training, 2018). Science, technology, engineering, and mathematics (STEM) subjects have also been identified as an important educational focus since 2015.
Under the orientations of the 2018 General Education Programme Initiative (Ministry of Education and Training, 2018), the teaching of Biology at the school level is expected to be able to promote

a) learner autonomy and self-reliance,
b) practical skills and application of biological knowledge in solving cognitive, practical, and technological problems,
c) experiential and project-based learning opportunities,
d) a variety of students' learning experience, including individual study, collaborative learning, flipped classrooms, and blended learning,
e) the use of ICT and rich educational resources in teaching and learning, and
f) the assessment of learning outcomes in alignment with desired competencies, particularly high-level cognitive competencies, and highly sought-after 21st-century skills.

To achieve these goals, the new curriculum calls for a shift from traditional methods of teaching and learning, such as a content-oriented learning environment, rote memorization of knowledge from students, and one-way delivery of knowledge from teachers to a learner-centered approach. Positive changes have been observed in the classroom. An example is the use of inquiry-based learning in Biology lessons. In projects where inquiry-based learning is introduced, students are reported to have been elevated from a passive role in acquiring biological knowledge to the role of active participants, explorers, and experimenters in their learning process (Dinh & Phan, 2018). However, some notable challenges include teachers' readiness to direct student inquiry and the time-intensive nature of inquiry-based activities. Another change in classroom practices is the embedding of biotechnology in secondary and high school biology content. Virtual Reality Technology (VRT), for example, has been introduced in several high schools in Vietnam to address the shortcomings of practice equipment shortages (Le & Do, 2019). Students are reported to be able to discover learning environments that would otherwise be inaccessible. Students' enthusiasm, interest, and curiosity to learn about the subject matter have also been acknowledged. Major challenges in using VRT, however, lie in the high costs for hardware and digital formats and the lack of professionally trained teachers to make effective use of VRT (Le & Do, 2019).

Methodology

Research Design

This study was a one-group pretest-posttest experimental design aiming to investigate the effectiveness of experiments in Biology education. One-group experimental design, according to Privitera and Alhlgrim-Delzell (2019), refers to observations of a single group that receives an intervention. The main disadvantage for this kind of design is the lack of a control group for comparison to be made regarding the effectiveness of the intervention used, which particularly threats internal validity when the same group of participants is observed over time. For this study, a one-group design was employed due to practical reasons, namely the limited availability of potential research sites with satisfactory experiment facilities and the small number of students enrolled in the biology teacher education courses at these sites. A pretest-posttest procedure was therefore employed to compare the performance of the group receiving the intervention and to minimize problems related to having no control group following the suggestion from Privitera and Alhlgrim-Delzell (2019).

Sampling

Regarding sampling, a total of 128 pre-service teachers who were enrolled in Biology teacher education courses at four teacher education colleges, participated in the study. The colleges were based in four northern provinces of Vietnam. The number of participating institutions, teacher trainers, and pre-service teachers is given in Table 1.

Table 1. *Sampling*

Institutions	*No. of pre-service teachers*	*No. of teacher trainers*
Hung Yen College of Education	16	1
Nghe An College of Education	47	1
Nam Dinh College of Education	41	1
Son La College of Education	24	1
Total	128	4

As teacher-training colleges, the participating institutions in this study offered their standard Biology teacher education courses in four years of coursework, which included a ten-week supervised teaching practicum in the third and fourth years. Following the core curriculum structure conditioned by Vietnam's Ministry of Education and Training (MOET), 15% of the biology teacher education courses at these institutions was allocated to general academic knowledge and skills, 60% to specialized academic knowledge and skills, and the remaining

25% provided pedagogical understanding and practices.

The pre-service teachers targeted were in their second year of coursework to ensure that they had received some fundamental training in performing an experiment in their first year and had been introduced to topics related to plant physiology. Plant physiology was one key content for Biology teacher education courses offered by the four colleges. It was also a key content in the general school Biology curriculum that pre-service teachers would need to cover in their future teaching. Aside from that, no other special arrangements were made to select the pre-service teachers. The four teacher trainers had at least three years of teaching experiment skills in laboratories and, for the duration of this study, were required to use experiments as a teaching strategy. Qualitative data was added through interviews with teacher trainers and pre-service teachers on the challenges in equipping experiment skills for pre-service teachers after the experimental courses.

Research Procedure

The research procedure involved some major activities. The first main activity was to investigate the extent to which experiments helped pre-service teachers improve their knowledge of the subject matter and their experiment skills. The four teacher trainers from the research sites were invited to participate as subject matter experts in a focus group discussion. The purpose of the discussion was to identify practical activities and materials that the institutions could use to improve the knowledge and experiment skills of pre-service teachers. Having formulated and agreed on a procedure to introduce experiments to pre-service teachers, the study then employed an experimental approach as described above using experiments as a pedagogical intervention. 128 pre-service teachers from four research sites were invited to take a pre-test before the intervention to determine what they had already obtained in terms of knowledge of the subject matter and experiment skills.

Next, interventions were organized at each research site. The experimental period for the four research sites spanned between 2015 and 2017. During each intervention, written tests and observations were used to assess pre-service teachers' progress in terms of the acquired skills and knowledge. When each intervention concluded, a post-test was administered to determine whether the biology knowledge and experiment skills of pre-service teachers improved in comparison with the results from the pre-tests.

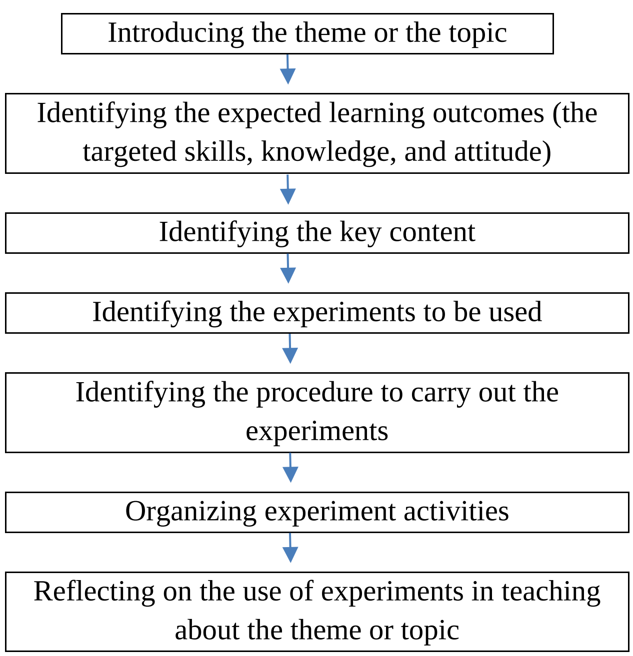

Figure 1. Procedure for using experiments

Reflection activities were also carried out to identify the challenges related to the training of experiment skills for pre-service teachers. Post-intervention interviews involved the four teacher trainers and 20 out of the 128 pre-service teachers who had taken part in the intervention. During the intervention, the teacher trainers followed the same procedure to introduce experiments to pre-service teachers. The procedure comprised seven steps as illustrated in the Figure 1

The impact of the intervention on pre-service teachers was evaluated in terms of four aspects, namely pre-service teachers' knowledge of plant physiology, knowledge of experiment procedures, skills to carry out experiments, and capacity to link future teaching practices.

Table 2 is a summary of the assessments used. Samples of these assessments are given in the Appendices.

Table 2. *Assessments of competency development*

Competencies assessed	*Assessment tools*	*No. of assessments used*
Knowledge of plant physiology	Written tests (Appendix 1)	1 pre-test, 1 progress, 1 post-test
Knowledge of experiment procedures	Written tests (Appendix 2)	1 pre-test, 1 post-test
Experiment skills	Rubric (Appendix 3)	Observation sheets
Capacity to link future teaching	Reflections, lesson plans	2 reflections; 2 lesson plans

There were:

a) Three written tests to assess pre-service teachers' knowledge of plant physiology. Each test consisted of 20 multiple-choice and open-ended questions; each question was worth 0.5 points. The total scores would then classify the knowledge attainment of pre-service teachers into one of the four levels:
   - 0 – 2.5 Recognition
   - 2.6 – 5.0 Comprehension
   - 5.1 – 7.5 Basic application
   - 7.5 – 10 Advanced applications

b) Two written tests, each comprising 20 multiple choice questions, to assess pre-service teachers' knowledge of experiment procedures.

c) An observation sheet to observe the performance of pre-service teachers in the laboratory. This sheet was used in combination with the experiment skills rubric (Appendix 3) that had been developed by the researchers and qualitatively validated with the subject matter experts.

d) Written self-reflections and two lesson plans prepared by pre-service teachers.

Post-intervention interview questions for teacher trainers were:

a) What are the challenges in teaching experiment skills for pre-service teachers?

b) What suggestions would you make to improve the procedure teaching experiment skills?

Post-intervention interview questions for pre-service teachers were:

a) What are the difficulties you encountered when learning experiment skills?

b) How will experiment skills help you with your future teaching?

c) What modifications would you make to improve the attainment of experiment skills?

The quantitative component of the study was the pre-test and post-test design. Quantitative data, including test scores, were analyzed using IBM SPSS Statistics software. The qualitative component of the study was the reflections collected from interviews with teacher trainers and pre-service teachers on the challenges in equipping experiment skills for pre-service teachers. Observational notes and transcribed interviews were entered in a word document and analyzed for emerging conceptual categories and interrelationships of categories and concepts. The procedure was aligned with Glaser et al. (1967) constant comparative method of qualitative analysis.

Results

The Effectiveness of Experiments as an Educational Measure in Training Pre-service Teachers

Pre-service teachers were assessed in terms of their knowledge of Plant Physiology, a subject of biology which was chosen as a sample course for this study, in three tests administered before, during, and after the intervention. The scores achieved by pre-service teachers in the three tests are given in **Table 3**. As can be seen, the mean and median scores increased through three tests. In the first test, the average score and median scores were at a low of 5.2 and 5.3 out of 10 respectively. These scores rose to 6.3 and 6.5 respectively in the second test, both followed by another increase to 7.0 in the last test. The minimum and maximum scores also increased, indicating an observable enrichment of students' knowledge throughout the intervention process.

Table 3. *Pre-service teachers' performance in written tests of Plant Physiology knowledge*

	Test 1	*Test 2*	*Test 3*
Total number of pre-service teachers	128	128	128
Mean score	5.219	6.328	7.039
Median	5.250	6.500	7.000
Mode	5.0	6.0	7.5
Standard deviation	1.2195	1.1813	1.2128
Variance	1.487	1.395	1.471
Minimum	2.0	4.0	4.0
Maximum	8.0	9.0	9.5

When the average scores were categorized into the four levels of biological knowledge attainment by pre-service teachers as shown in **Table 4**, it is obvious that in the first test, knowledge attainment capacity among students was mainly at Level 1 and Level 2, indicating students' low level of theoretical knowledge. However, the high percentage of pre-service teachers being placed in Level 3 and Level 4 when the next two tests were administered illustrated an improvement in pre-service teachers' knowledge of the subject.

Table 4. *Pre-service teachers placed into levels of theoretical knowledge attainment (%) in 3 tests*

	Test 1	*Test 2*	*Test 3*
Level 1	3.8	3.0	3.0
Level 2	41.7	20.5	9.1
Level 3	47.7	69.7	65.9
Level 4	3.8	6.8	22.0

The data collected from the observations of pre-service teachers' performance in the laboratory showed a significant improvement in the acquisition of experiment skills among pre-service teachers. **Error! Reference source not found.** Illustrates the improvement in three aspects of experiment skills by pre-service teachers in three observations while Table 6 illustrates the overall improvement in pre-service teachers' experiment skills.

Observation 1 was made near the start of the intervention course; observation 2 was reported for the middle of the course; observation 3 was recorded near the end of the intervention. As shown in **Table 6**, the percentage of pre-service teachers placed at Level 1 and Level 2 declined respectively to 0% and 11.72% in the third observation.

Table 5. *Pre-service teachers placed into levels of experiment skills in three observations (%)*

	Identifying the scientific basis for experiments			*Identifying experiment procedures*			*Determining how to collect, observe, and process data*		
Level	Ob1	Ob2	Ob3	Ob1	Ob2	Ob3	Ob1	Ob2	Ob3
1	3.91	1.56	0.00	11.72	9.38	5.47	14.06	9.38	3.91
2	66.09	46.09	36.72	57.81	53.91	51.56	65.63	61.72	43.75
3	29.69	52.34	63.28	30.47	36.72	42.97	20.31	28.91	52.34

*Ob= observation

Table 6. *Pre-service teachers placed into levels of experiment skills attainment (%) in 3 observations*

	Observation 1	*Observation 2*	*Observation 3*
Level 1	2.34	0.78	0.0
Level 2	60.94	43.63	11.72
Level 3	36.72	54.5	72.65

The results of the pre-test and post-test in Figure 2 revealed positive changes in levels of knowledge and experiment skill acquisition after the intervention. Specifically, in the pre-test, pre-service teachers commonly scored 3, 3.5, and 4 out of 10. No pre-service teachers achieved scores of 7.5 and above. Before the intervention, 88.3% of the pre-service teachers were at the recognition and comprehension levels whereas no pre-service teachers were placed at the advanced application level. After the intervention, the most common scores were 6 to 8, accounting for 76.6%. No pre-service teachers scored 3.5 and below and 9.1% scored high at 8 and above in the post-test.

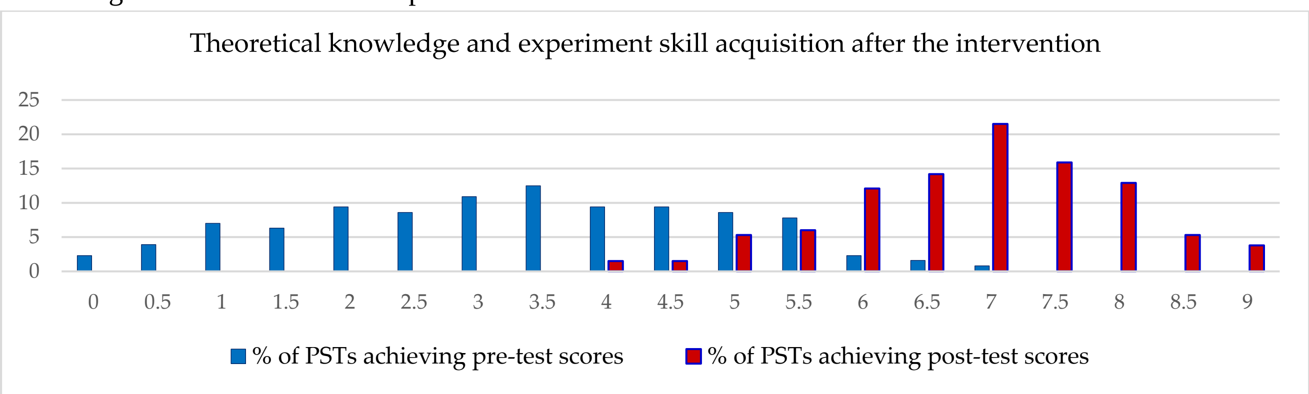

Figure 2. Results of pre-test and post-test (n = 128)

This means that most pre-service teachers undertaking the experimental course gained a significant improvement in the knowledge of the subject matter and the experiment skills. The effectiveness of the intervention on the improvement of knowledge and skill acquisition was confirmed.

Factors Affecting the Acquisition of Experiment Skills

Interviews with 4 teacher trainers and 20 pre-service teachers taking part in the experimental courses revealed several difficulties in the application of experimentation to cultivate experiment skills for pre-service teachers (Figure 3).

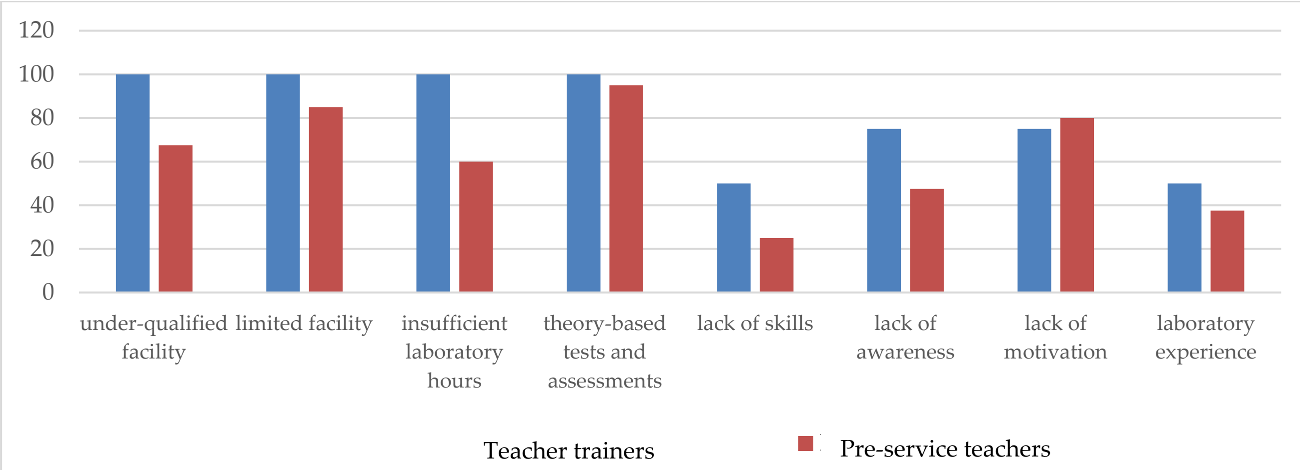

Figure 3. Major challenges in the acquisition of experiment skills to pre-service Biology teachers

Figure 3 reveals eight major challenges to the acquisition of experiment skills of pre-service Biology teachers, which can be categorized into four major factors. School factors included facility limited in terms of quantity and quality. Curriculum factors involved insufficient experiment hours and a persisting heavily exam-oriented teaching and assessment culture. Teacher trainer factors, meanwhile, concerned a lack of experiment skills while the pre-service teacher factor was mostly concerned with a lack of motivation and laboratory experience. All the teacher trainers interviewed were aware of the constraints from the school and curriculum factors. From the side of pre-service teachers, 60% regarded their current school factors to be inhibiting to the use of experiments in their training courses and 95% regarded the curriculum as the limiting factor.

Discussion

The findings from the study confirm the effectiveness of experiments in improving the knowledge of the subject matter and the experiment skills for pre-service Biology teachers. The finding echoes what Dresner et al. (2014) found regarding the attainment of the high-level cognitive capacity of pre-service teachers following an intervention where experiments were used as an educational approach. The findings from Dresner et al. (2014) revealed that pre-service teachers had a longer knowledge retention rate when exposed to laboratory work than those without laboratory work. Wenglinsky (2000) also came to the same conclusion about the effectiveness of experiment courses, noting that students whose teachers had been trained in experiment-embedded teacher-training courses performed more successfully academically and participated in the science projects more frequently than students whose teachers had not taken such courses.

Almroth (2015) highlighted the importance of laboratory work to experiment skill development by emphasizing the value of the experimental teaching procedure. Like many of these findings, the intervention described in the current research involved inquiry-based activities during which pre-service teachers were provided with opportunities to get engaged in authentic research, collaborate with peers, and practice presenting results. Specifically, open-ended questions were valued to have facilitated problem-solving and critical-thinking skills while group work was beneficial to communication and collaboration skills. These types of interactions would, in the long run, cultivate many skills other than experiment skills that could produce a teacher confident and competent to deliver Biology lessons as remarked by Harman et al. (2016).

Responses to the interview questions showed that major challenges to the acquisition of experiment skills were concerned with facility shortages, a lack of experiment knowledge and skills among trainers, and a lack of motivation and skills among pre-service teachers. The finding accords with reflections already presented in research on the same theme such as (Gobaw & Atagana, 2016; Harman et al., 2016; Kang & Wallace, 2005).

Despite the policy of the Vietnamese Government to invest further in upgrading the infrastructure for teacher education institutions, facilitating all teacher education institutions with sufficient equipment for experiment practices is infeasible in the limited economic condition of Vietnam.

The current theory-based and overloaded curriculum at many teacher education institutions in Vietnam is another attribution to the challenges in enhancing trainers' and pre-service teachers' experiment skills. As a trainer reported, experiment-embedded instruction was generally delivered once a month, which was of a rather low frequency for important experiment skills to be mastered. The shortages in experiment facilities and curriculum were also considered the causes of motivation loss for pre-service teachers since this could discourage pre-service teachers from practicing experiment skills at an adequate frequency and in a full procedure. It should be noted that many pre-service teachers had barely been exposed to biological experiments in earlier educational stages, making the acquisition of experiment skills of pre-service teachers at higher education institutions more challenging. Kloser et al. (2011), in agreement with this conclusion, recommended lowering the requirements for performing experiments by using low barrier technical expertise or a constrained set of hypotheses and allowing lecturers to use their specific field of expertise to foster high-level discussions in the subject matter. In so doing, pre-service teachers were more likely to feel motivated to perform experiment practices.

Underlying a complexity of three key components of educators' knowledge, namely understanding of content, understanding of teaching, and understanding of technology, TPACK has become a popular framework for teacher education systems to follow (Koehler & Mishra, 2009; Kurt, 2019). It is interesting to note that analyses of the procedure of teaching experimentation to pre-service teachers of Biology reveal a compatible association between types of knowledge in TPACK and aspects related to experimentation. Specifically, technological knowledge can be associated with experiment skills; content knowledge can be associated with theoretical knowledge acquisition, and pedagogical knowledge can be associated with teaching skills attained by pre-service teachers of Biology. This means that teaching experiment skills for pre-service teachers of Biology, when implemented in the right procedure with the right methods, is an essential part of the TPACK chain that can help produce competent and confident future teachers of Biology.

Conclusion

The current study investigated the effectiveness of experiments in improving knowledge and experiment skills for pre-service Biology teachers at several teacher training institutions in Vietnam. By using experiment-driven courses as an intervention for 128 pre-service teachers at four teacher education institutions, the study has obtained positive results regarding the contributions of experimentation teaching in Biology education to the improvement of knowledge attainment and experiment skills for pre-service teachers of Biology. Additionally, answers to interviews by teacher trainers and pre-service teachers in the intervention showed four factors affecting the acquisition of experiment skills, namely school, curriculum, teacher trainer and pre-service teacher factors. As such, to better train a teacher to become competent in their future teaching of Biology, the equipment and methodology for embedding experiments in the instruction of teacher education courses need to be sufficiently provided. The research findings are expected to contribute to the quality improvement of teaching experiment skills in the subject of Biology in Vietnam as well as extending the literature on the acquisition of experiment skills among pre-service Biology teachers.

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Appendices

Appendix 1. Sample of written test to assess knowledge of plant physiology

Question 1. Describe what happens when we cut across the trunk of a tomato plant about 5 cm from the ground. What dynamics of the tree cause that phenomenon?

Question 2. Describe and explain what happens when we peel 3cm off the bark around a branch or a trunk.

Question 3. Place a white dahlia flower with a 10cm-long stalk in a glass of red liquid for 1-2 days. What happens to the petals? Describe the phenomenon and explain the reasons.

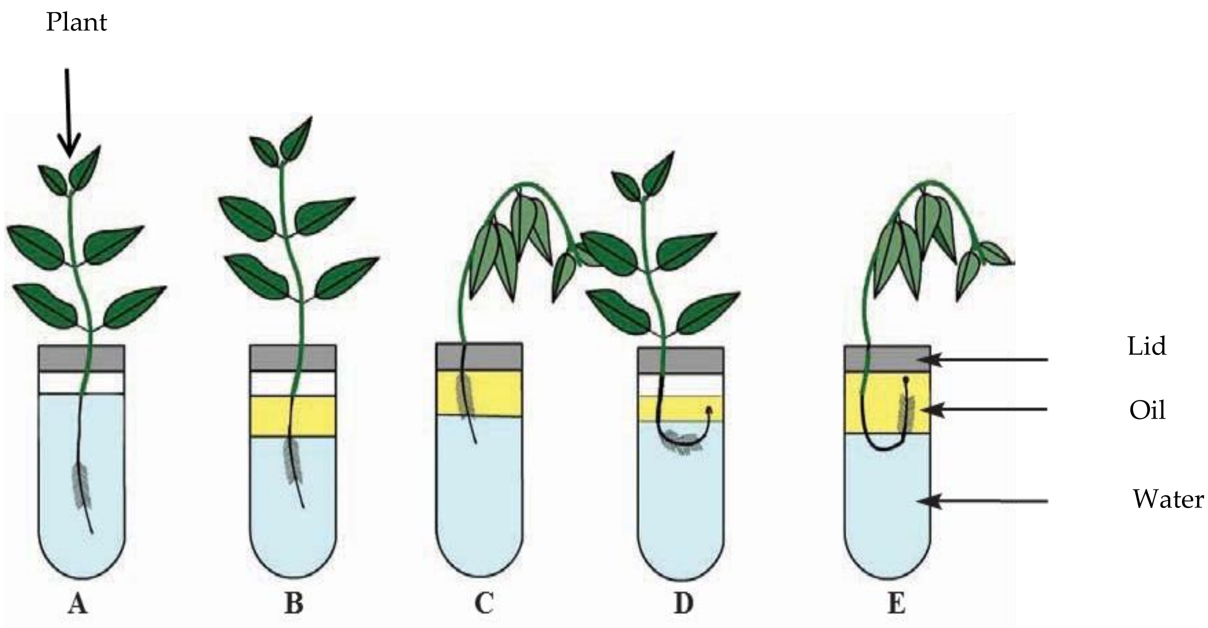
Question 4. In an experiment, sun rays are projected through a prism on a long strand of algae which is submerged in a solution with aerobic bacteria. Observing the solution under the microscope, it can be seen that

a. The bacteria gather at both ends of algae fibers. Explain the phenomenon.
b. The number of bacteria concentrating at both ends of algae fibers differs significantly. Explain the phenomenon and draw scientific conclusions from the experiment.

Question 5. A scientist injects ascorbic acid crystals (a strong reducing agent) into a test tube containing red methyl solution (a strong oxidizing agent which is colorless in its reducing state and red in its oxidizing state) until saturation occurs and the solution remains red. The scientist then adds a moderate amount of chlorophyll that is freshly extracted from some leaves to the test tube. When placed under the sunlight, the solution in the test tube changes from red to green.

a. Explain the experiment results.
b. Explain the significance of this experiment.

Question 6. A student performs a biological experiment in the following steps



a. Describe the steps of the experiment above.
b. Provide a scientific hypothesis for the experiment above.
c. What scientific conclusion can you draw from the experiment above?

Appendix 2. Sample of MCQ test to assess pre-service teachers' knowledge of experiment procedures

Question 1. You are about to enter the plant physiology laboratory. What protective clothing do you need to protect yourself?

Question 2. What should one do when they take HCl 1% acid solution by accident?

a. Gargle and drink cold water containing MgO.
b. Gargle and drink cold water containing CH3COOH 1%.
c. Gargle and drink cold water containing NaCl.
d. Gargle and drink cold, distilled water.

Question 3. What should one do when they take NaOH 1% solution by accident?

a. Gargle and drink cold water containing MgO.
b. Gargle and drink cold water containing CH3COOH 1%.
c. Gargle and drink cold water containing NaCl.
d. Gargle and drink cold, distilled water.

Question 4. While Student A is diluting HCl 36% solution, the chemical accidentally contacts their hand skin, causing burns. What should Student A do?

a. Wash hands under running water and apply NaHCO3 1% solution.
b. Wash hands under running water and apply acetic acid 1% solution.
c. Wash hands under running water and apply NaCl 1% solution.
d. Wash hands under running water and apply NaOH 1% solution.

Appendix 3. Rubric to assess experiment skills

Dimensions	Levels	Descriptors
Identifying objectives of experiments	3	Can identify the objectives quickly and independently
	2	Can identify the objectives provided with some guidance
	1	Can identify the objectives but in a general manner and when guided
Identifying the scientific basis for experiments	3	Can identify the scientific basis for experiments quickly and accurately
	2	Can identify the scientific basis for experiments when guided
	1	Can identify part of the scientific basis for experiments when guided
Identifying dependent and independent variables	3	Can identify variables quickly and accurately
	2	Can identify variables when guided
	1	Can identify parts of the variables when guided though with inaccuracy
Identifying experiment procedures	3	Can determine a logical and accurate experiment procedure
	2	Can identify steps in an experiment procedure though with uncertainty
	1	Can identify steps in an experiment procedure though with inaccuracy
Identifying chemicals and instruments needed	3	Can identify instruments/chemicals needed in correct quantities/ types
	2	Can identify instruments and chemicals needed though quantities and types may not be accurate
	1	Can name most instruments and chemicals needed but have difficulties identifying correct quantities
Determining how to collect, observe, and process data	3	Can determine the correct time and methods to observe, track, and process data
	2	Can determine the time and ways to observe, track, and process data though with some inaccuracy
	1	Have difficulties determining the time and methods to observe, track, and process data
Presenting results graphically	3	Can present results in graphic forms accurately and logically
	2	Can present results in graphic forms that show the relationship between the variables though with some inaccuracy
	1	Can present results in some graphic forms but lacking the relationship between the variables and lacking accuracy

Observation sheet

OBSERVATION SHEET

Experiment skills

Pre-service teachers' name:

Faculty/ College:

Assessor:

Assessed content: Experiment skills

Dimensions	Description of pre-service teachers' performances	Rating (Level)	Notes

Level achieved ________________