The impact of inquiry-based laboratories on improving pre-service teachers' experimental competency

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Abstract

In this article, we analyze how inquiry-based laboratories affect the experimental competency of pre-service physics teachers. An experimental quantitative analysis method, the static-group pretest-posttest design, has been utilized. A total of 32 pre-service physics teachers participated in the experimental group and 14 in the control group. In order to observe the experimental competency development level of pre-service physics teachers, the physics lab inventory of critical thinking (PLIC) test and experimental competency test have been used. The findings revealed that inquiry-based laboratories are remarkably effective in developing pre-service physics teachers' experimental competency. The growth rate of behavioral indicators is relatively uniform except for two behaviors: (2.7) Propose ideas to improve experimental equipment and (4.5) Propose measures to reduce error. In addition, the development of pre-service teachers' experimental competency has reached a high level, but the percentage of students reaching level 3 is still low (14.63%). In level 3, pre-service teachers design their own experimental plans and carry them out in new situations almost without the support of teachers. Therefore, it is suggested that further research is needed to focus on increasing the support of teachers at level 3 by providing additional experimental equipment while simultaneously enhancing interaction channels between teachers and students through MS Teams and expanding the sample size.

Introduction

Inquiry-based laboratory (IBL) is understood as the way learners organize their use of experiments to acquire knowledge and form personal competency through conducting experiments under different openness levels, depending on the amount of information provided to them. IBL is widely applied in biology laboratory courses at universities (Gormally, 2016). IBL is utilized in the experimental module to develop students' self-reliance (Smallhorn, Young, Hunter & Da Silva, 2015). IBL approaches are more student-involved evoke inductive reasoning and develop scientific process skills, such as forming a hypothesis, identifying, and manipulating experimental variables, and making discussions and conclusions from the data (Kolkhorst, Mason, DiPasquale, Patterson, & Buono, 2001). The IBL course enabled students to explore the limits of their expertise (realize what their knowns and unknowns are in the subject), allowing students to acquire knowledge as professional scientists would do as well as help them organize practical activities in schools (Naiker & Wakeling, 2015). A study of Nivalainen, Asikainen, and Hirvonen (2013) examines the use of an IBL course, in which students plan and conduct hands-on activities to use in teaching high-school students (Nivalainen et al., 2013). Other research shows that students prefer IBL to the traditional laboratory as IBL is more interesting to them. (Siddiqui, Zadmik, Shapter, & Schmidt, 2013; Nadeem, Chandra, Livirya, & Beryozkina, 2020; Baloyi, 2017; Berg, Bergendahl, Lundberg,

& Tibell, 2003; Shi, Ma, & Wang, 2020). Nadeem et al. also show that IBL helps students to adapt to the lab environment and familiarize themselves with the lab equipment, staff, and safety rules in a fun and interactive manner. IBL has fostered the development of students' scientific reasoning skills and experimental design skills (Blumer & Beck, 2019). IBL has created many good opportunities for students to develop their experimental competency. IBL enables the learners who take part in the process to actively utilize problem-solving skills and to improve pre-service science teachers' experimental competency (Yakar & Baykara, 2014). Some researchers suggest re-designing traditional lab activities into IBL to develop chemistry students' experimental competency (Imaduddin & Hidayah, 2019); and that of biochemistry students (Johnson, Savas, Kartje, & Hoops, 2014). However, there are currently no studies using IBL to improve the experimental competency of pre-service physics teachers. Experimental competency is a key trait that is for physics teachers and needs to be formed and developed through the process of conducting experiments; it is the ability to successfully carry out experimental tasks in a specific context using one's knowledge, skills, and techniques regarding the experimental process, along with other psychological attributes such as interest, confidence, or willpower. According to Etkina et al. (2006), experimental competency is the ability to describe some of the most important procedures, processes, and methods that scientists have used to create knowledge and solve experimental problems. Etkina et al. have built a set of formative assessment tasks and rubrics for the introductory Physics course to help students assess their experimental competencies (Etkina et al., 2006). Bitzenbauer and Meyn (2021) found that the experimental competency of prospective physics teachers must not only be encouraged in the context of lab courses (focusing on content knowledge CK), but also in the context of didactic education (linking CK and pedagogical content knowledge PCK). They report a new seminar concept for students in physics teacher study programs. This concept is based on the current state of research in physics education, on the teachers' professional competencies, and the modeling of experimental competency. Bitzenbauer and Meyn (2021) have conducted a pilot study to evaluate the seminar concept of basic experimental techniques. A study of Bitzenbauer and Meyn utilizes a test instrument derived from physics education research to evaluate the experimental skills of prospective physics teachers before and after the seminar. Pre-test results highlighted that some prospective physics teachers lack fundamental experimental techniques, despite completing standard laboratory courses successfully. This underscores the need for the proposed new seminar concept for teacher training. Theyßen et al. (2014) proposed a model of experimental competencies in Physics consisting of three main phases of the experimental process: "preparation", "performance", and "data analysis", containing some smaller components in each. The model focuses on the performance phase, such as assembling the experimental setup, as well as performing and documenting measurements. Their results confirmed the comprehensiveness of the model and the high relevance of all its components for the description of lab work. At the same time, the authors also developed a viable and reliable rubric for experimental competencies. The reliability of the research instrument was satisfactory (Cronbach's α >.70) (Theyßen et al., 2014; Theyßen, Schecker, Neumann, Eickhorst, & Dickmann, 2016). The American Association of Physics Teachers (AAPT) (2014) has made recommendations to foster the development of many key 21st century skills and experimental competencies. The AAPT has prepared a document proposing lab guidelines to enhance students' experiment designs and practical laboratory skills, as well as analyzing and visualizing data. The recommended learning outcomes presented in this document are not a complete description of experiments and techniques, instead, they have guidelines with two levels (introductory and advanced) for developing lab curricula (Kozminski et al., 2014). In a recent study, a structural framework of experimental competence in the General Physics Laboratory module was proposed according to the increasing levels of self-reliance of pre-service physics teachers in Vietnam (Loan, Bien, &

Chat, 2021). The competency framework consists of 4 components (Determine the purpose of the experiment; Design the experimental plan; Arrange and conduct the experiment; Process data; Analyze and Evaluate the results) with 21 behavioral indicators. Nevertheless, this study has not yet been organized to assess the level of achievement of the behavioral indicators in the competency framework (Loan et al., 2021). Therefore, this article focuses on analyzing the effects of the inquiry-based laboratory on the experimental competency of pre-service physics teachers in the General Physics Laboratory course. Toward achieving this goal, we address the following two research questions (RQ):

RQ1: Do inquiry-based laboratories improve pre-service teachers' experimental competency in the General Physics Laboratory course?

RQ2: What are the behavioral indicators in the experimental competency framework of pre-service teachers that are developed through inquiry-based laboratories, and which indicators are the most and least developed? Additionally, what is the level of experimental competency development among pre-service teachers after taking this course?

Experimental competency framework

Experimental competency includes 4 sub-competences: *determine the purpose of the experiment*; *design experimental plan* (including the selection of experimental equipment, planning how to conduct and collect data during the experiment); *set-up and conduct the experiment* (assembling, arranging experiment, collecting experiment results); *process data and analyze*, *evaluate the results* (Loan et al., 2021).

In this study, students' experimental competency is assessed based on the experimental competency framework that we have built. This experimental competency framework consists of 4 sub-competences and 21 behavioral indicators. The details are shown in Table 1 below:

Table 1. The experimental competency structure framework (Loan et al., 2021)

1. Determine the purpose of the experiment
(1.1) Make observations of the phenomena and determine related knowledge
(1.2) Make logical inferences to find the consequences to be tested
(1.3) Determine the purpose of the experiment
2. Design the experimental plan
(2.1) Determine the experiment instruments to be used
(2.2) Determine the experimental arrangement
(2.3) Plan steps to conduct the experiment
(2.4) Plan how to collect data
(2.5) Plan how to process data
(2.6) Evaluate the selection of suitable options
(2.7) Propose ideas to improve experimental equipment
3. Set-up and conduct the experiment
(3.1) Find out the parts of real equipment corresponding to the constructed plan
(3.2) Assemble, arrange, and conduct the experiment with real equipment
(3.3) Perform the planned experiment on real equipment
(3.4) Collect and present data
4. Process data and analyze, and evaluate the results
(4.1) Process data and draw results
(4.2) Draw conclusions from experimental results
(4.3) Present the experiment report
(4.4) Determine the cause of the error
(4.5) Propose measures to reduce error
(4.6) Evaluate the advantages and disadvantages of the experimental plan

(4.7) Improve experimental equipment

The experimental competency framework consists of 21 behavioral indicators. Each behavioral indicator is rated on three levels. Therefore, there will be 63 behavioral quality criteria. The description of the three behavioral levels is as follows:
+ **Level 1**: Students perform the behaviors following given instructions, i.e. the things students need to do in the research process are written explicitly and students perform the behaviors according to the description of the steps in the document or are guided by the teacher.
+ **Level 2**: Students perform the same behavior with the existing experimental plan, but the teacher leaves it open in terms of experimental tools or how to conduct the experiments. The teacher replaces some or all the experimental equipment.
+ **Level 3**: Students perform their own acts in new situations. Students determine the purpose of the experiment by themselves but are limited to the scope of thermomechanical experiments and make their own plans on the proposed experiment, including designing the experimental plan, selecting equipment, set-up, implementing the proposed plan and processing data.

Methodology of research

Research participants
Forty-six pre-service physics teachers enrolled in the General Physics Laboratory in the Spring Term of 2022 were invited to participate in the study (including the experimental group and control group). There were 32 males and 14 females. All participants were informed of the study and signed the consent form to participate in the study voluntarily (Please see Appendix Participant Consent Form). They were second-year pre-service physics teachers at Ho Chi Minh University of Education in Viet Nam. The lab module focuses on experiments in introductory mechanics and thermodynamics. In this study, a quantitative research method has been utilized to investigate the effect of IBL applied in the General Physics Laboratory course on the development of students' experimental competency. In this study, the static-group pretest-posttest design, which is a scientific research pattern, has been used. The participants were divided into an experimental group and a control group. We applied IBL to the experimental group, while the control group learned through the traditional method (the practice method). The experimental group was split into 2 classes. We selected 3 classes of equal levels and randomly distributed them, so there were 2 experimental classes and 1 control class. Experimental class 1 (G1) included 16 pre-service teachers. Experimental class 2 (G2) included 16 pre-service teachers. The control class (G3) included 14 pre-service teachers. Students in each class worked in pairs to complete experimental activities in 12 weeks. In order for the effect to be observed on dependent variables, a pre-test PLIC and a post-test PLIC have been utilized (Quinn, Walsch, & Holmes, 2018). The research design of the experimental method is illustrated in Table 2.

Table 2 - Experimental research design

Class	N	Pre-test	Treatment	Post-test
G1	**16**	**O_1**	**X**	**O_2**
G2	**16**	**O_1**	**X**	**O_2**
G3	**14**	**O_1**	**---**	**O_2**

Annotation: N = number of samples; O_1 = pre-test; X = treatment (learning with Inquiry- based learning); O_2 = post-test; G1 and G2: experimental group; G3: control group

Table 3 – The impact plan

Week	Weekly activities	Allocated time
1	Introduce, Measure, and analyze measurement results, application of the pre-tests: PLIC, ECT	**4 hours**
2-10	Carrying out 9 experiments, Students do 1 experiment per week with 3 inquiry levels: **Level 1*: conduct experiments according to available samples** **Level 2*: conduct experiments with similar situations** **Level 3*: conduct experiments in new situations**	**36 hours**
11	Report production design experimental plan	**4 hours**
12	Application of the post-tests: PLIC, ECT	**4 hours**
Total		**48 hours**

* Inquiry Level 1 (inquiry according to the available samples): Students are provided with experimental purposes, experimental tools, and experimental plans. Students perform experiments according to the manual document to find the answer with the complete guidance of the teacher.
* Inquiry Level 2 (guided inquiry): Students are provided with experimental purposes, experimental tools, and experimental plans. Students conduct experiments in a situation like Task 1 with the partial guidance of teachers.
* Inquiry level 3 (open inquiry): Students are completely independent in detecting problems to inquiry, almost without the support of teachers. The teacher only plays the role of an advisor to confirm or give suggestions to students. Students on their own determine the purposes of the experiment, design the experimental plan, conduct the experiment according to the proposed plan, and process the data.
The experimental class is organized to be taught according to the impact of the IBL procedure in the General Physics Laboratory course, as shown in Figure 1. The control class was organized according to the practical method, and the students experimented with the steps available in the documentation.

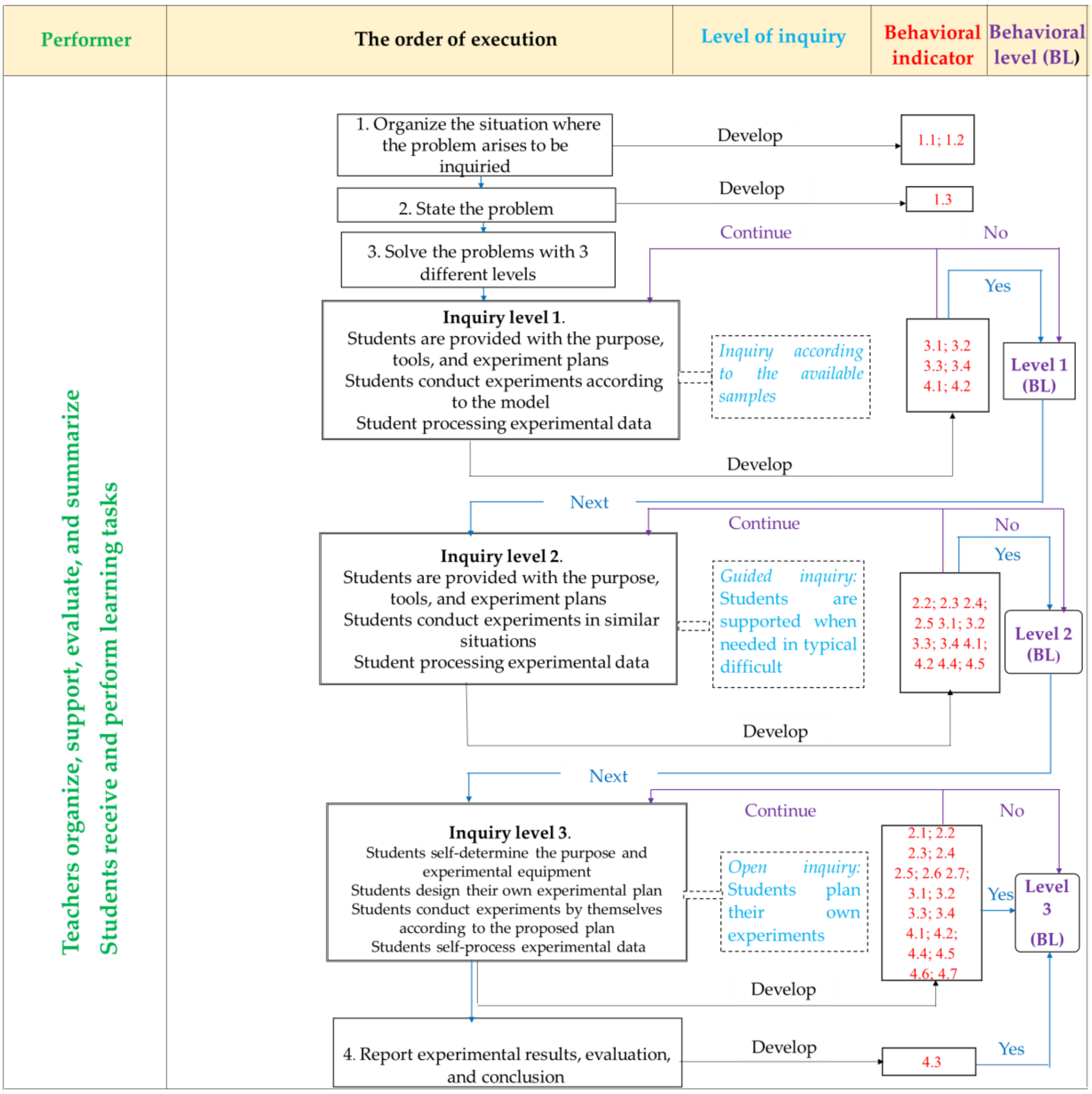

Figure 1. IBL procedure in the General Physics Laboratory course

Research instruments:

PLIC test

In this study, the PLIC test has been used as a tool for data collection. The PLIC test is developed by Walsh, Quinn, Wieman, and Holmes (2019) and is used for measuring students' experimental competency. The PLIC is a standardized assessment instrument to determine the degree to which students develop these skills through instructional labs. The PLIC context presents students with two case studies of groups conducting a mass-on-a-spring experiment to test the relationship between the period of oscillation and mass attached to the spring based on the following formula that: $T = 2\pi\sqrt{\frac{m}{k}}$. Group 1 conducts 10 repeated trials for the period of oscillation for two different masses, uses the equation to find the spring constant (k) in each case, and compares the values. Group 2 conducts two repeated trials for the period of oscillation for 10 different masses, and plots T^2 versus M. The PLIC poses questions asking students to: interpret and evaluate the sample data, evaluate the models, evaluate the methods, and suggest what the group should do next. The PLIC is a 10-question, closed-response assessment that probes student critical thinking skills in the context of physics experimentation. There is a combination of question formats, including five-point Likert-scale questions, traditional multiple-choice questions, and multiple-response questions. The PLIC test is composed of four scales (evaluating models, evaluating methods, suggesting follow-ups, and normalized score) and these scales aim to test a part of experimental competencies (Quinn et al., 2018; Walsh et al., 2019).

The PLIC test is used to check the level of the control and experimental groups. However, the PLIC test only evaluates some behavioral indicators in the experimental competency structure framework of Table 1. Therefore, we have built an additional experimental competence test (ECT) to fill in the gap that the PLIC test has not yet assessed regarding the rest of the experimental competence.

Experimental competency test (ECT)

The experimental competency test is prepared by our research team and built on our experimental competency framework. The ECT is used for measuring the development of behavioral indicators in the experimental competency framework (Loan et al., 2021) and consists of 12 multiple-choice and essay questions. The questions in the ECT include determining the purpose of the experiment (1 question), designing the experimental plan (3 questions), setting-up and conducting the experiment (5 questions), processing data, analyzing, and evaluating the results (3 questions). The ECT focuses on evaluating behavioral indicators with the most frequency, which are: (1.3); (2.1); (2.2); (2.3); (2.4); (2.5); (2.7); (3.1); (3.2); (3.3); (3.4); (4.1); (4.2); (4.3); (4.4); (4.5) (i.e. the behavioral indicators in Table 1).

We have evaluated the reliability of the results of the experimental competency test through 3 independent assessment rounds. We have tested the similarity between several independent reviewers. In the first round, two independent examiners marked the three pre-tests. The rate of agreement among the two examiners was 97.5%. In the second round, two examiners independently scored once again with 6 random tests from 2 groups of pre-tests (3 items) and post-tests (3 items; the rate of agreement amongst examiners was 92.4%, which was lower due to the more subjective nature of marking essay questions. In the final round, the two examiners discussed and agreed on several scoring criteria in the rubric for evaluating essay questions. After discussion, 2 independent examiners marked 3 post-tests at random, and the consensus rate was about 98%. The results of Pearson correlation analysis show that the total test scores between the two examiners are closely correlated $r = .911$ (sig. $=0.012<0.05$) for the pre-test and $r=.987$ (with value sig.$=0.000 <0.05$) for the post-test (see Figure 2).
The reliability of the test is to indicate that the test is suitable to be used in this study.

Descriptive Statistics

	Mean	Std. Deviation	N
GK1_Pre	55.67	8.710	6
GK2_Pre	59.500	11.8828	6

Descriptive Statistics

	Mean	Std. Deviation	N
GK1_Post	64.67	16.943	6
GK2_Post	66.50	18.031	6

Correlations

		GK1_Pre	GK2_Pre
GK1_Pre	Pearson Correlation	1	.911*
	Sig. (2-tailed)		.012
	N	6	6
GK2_Pre	Pearson Correlation	.911*	1
	Sig. (2-tailed)	.012	
	N	6	6

*. Correlation is significant at the 0.05 level (2-tailed).

Correlations

		GK1_Post	GK2_Post
GK1_Post	Pearson Correlation	1	.987**
	Sig. (2-tailed)		.000
	N	6	6
GK2_Post	Pearson Correlation	.987**	1
	Sig. (2-tailed)	.000	
	N	6	6

**. Correlation is significant at the 0.01 level (2-tailed).

Figure 2. The results of Pearson correlation analysis of two examiners marked for pre-test (left figure) and post-test (right figure)

Data collection

This study was conducted during the General Physics Laboratory course in the Spring Term. The contents of the experiments consist of an introduction unit and nine experiments units which were designed with inquiry-based learning tasks with increasing levels, performed, and presented by pre-service teachers in such a way that each experiment lasted one week within a total of 12 weeks (48 hours). At the very beginning of the study, the pre-service teachers were informed by the researcher about the detailed outline of the General Physics Laboratory course and how to organize inquiry-based learning, as well as how they are evaluated in the course. To begin with, the PLIC test and experimental competency test (ECT) were applied to pre-service teachers as pre-tests. The purpose of the pre-test is to check the level of the control group and the experimental group. In the final week, PLIC and ECT post-tests were applied to pre-service teachers. The purpose of the post-test is to compare the learning results of the two control and experimental groups and to evaluate the effect of the treatment before and after the pedagogical experiment. The pre-service teachers take both the PLIC test and ECT online and face-to-face in the laboratory. Moreover, in this study, we also collect experimental data through video recordings (using Microsoft Teams), observations, learning products, and surveys. The measurement of pre-service teachers' experimental competency is done through assessment of the recordings and learning products; after finishing each experiment, pre-service teachers assess the level of achievement of behavioral indicators in the rubric table according to 3 levels of behavior (including self-assessment and peer assessment).

Analysis of data

The data obtained has been evaluated using a variety of analysis methods available in SPSS 20. In order for us to choose among the parametric and nonparametric tests that would be used in the evaluation of data collected from research, these data were tested foor normality (based on a Kolmogorov-Smirnov and Shapiro-Wilk test). To illustrate whether there was a meaningful difference between pre-test and post-test scores, the PLIC test, ECT, and paired samples t-test were used. Furthermore, we used Excel software to draw spider web charts to assess the development of behavioral indicators in the experimental competency framework.

Results

This study aims to observe the pre-service teachers' experimental competency development level. In this part, the data collected through the measurements applied as the pre-test and post-test that were administered according to the method of the study and the experimental competency tests are analyzed, and the results are presented.

In order to determine the analysis method to be used in this research, it was necessary to find out whether the results of the experimental competency test that were applied as pre-and post-tests were normally distributed. For this purpose, the Kolmogorov-Smirnov test and Shapiro-Wilk test were applied to the data gathered through pre and post-tests. The results showed that all pre- and post-test achievements related to the two measurement devices were normally distributed (Kolmogorov-Smirnov test $p=.20>.05$; Shapiro-Wilk test $p=.34>.05$). Thus, parametric tests were used to analyze the data.

The first new result answered research question 1:
Evaluate the effectiveness of IBL for developing pre-service teachers' experimental competency based on the results of the PLIC test and ECT.

The result of PLIC test
The data on the experimental competency gathered from the research group were evaluated through a paired sample t-test with the $p<.05$ level. The results are shown in Table 4 (experimental group) and Table 5 (control group).

Firstly, the mean score of the pre-test PLIC of pre-service teachers' experimental competency is 0.32, and the post-test average is 0.43 in the experimental group. This result shows that there is a statistical difference between the pre and post-tests of the pre-service teachers in the experimental group, and the difference is positive for the post-test ($t=-3.530$, $p<.05$). Based on the result, it is possible to say that the inquiry-based laboratories are effective in developing the experimental competency of pre-service teachers.

Secondly, regarding the control group, the mean score of the pre-test PLIC of pre-service teachers' experimental competency is 0.36, and the post-test average is 0.37, which almost stays the same. This result also shows that there is no statistical difference between the pre and post-tests of the pre-service teachers in the control group, and it is negative for the post-test ($t=-0.404$, $p>.05$).

Table 4 – **The t-test comparison of pre-and post-test results of the PLIC test of pre-service teachers in the experimental group (consist of G1 and G2)**

	N	*M*	*SD*	*SE*	*t*	*p*
Pre-test	26	0.328	0.129	0.025	-3.530	.002*
Post-test	26	0.432	0.068	0.013		

(*p< .05)
Annotation: 6 pre-service teachers did not complete the tests

Table 5 - The t-test comparison of pre-and post-test results of the PLIC test of pre-service teachers in the control group (G3)

	N	*M*	*SD*	*SE*	*t*	*p*
Pre-test	11	0.360	0.122	0.036	-0.404	.694**
Post-test	11	0.377	0.084	0.025		

(**p> .05)
Annotation: 3 pre-service teachers did not complete the tests.

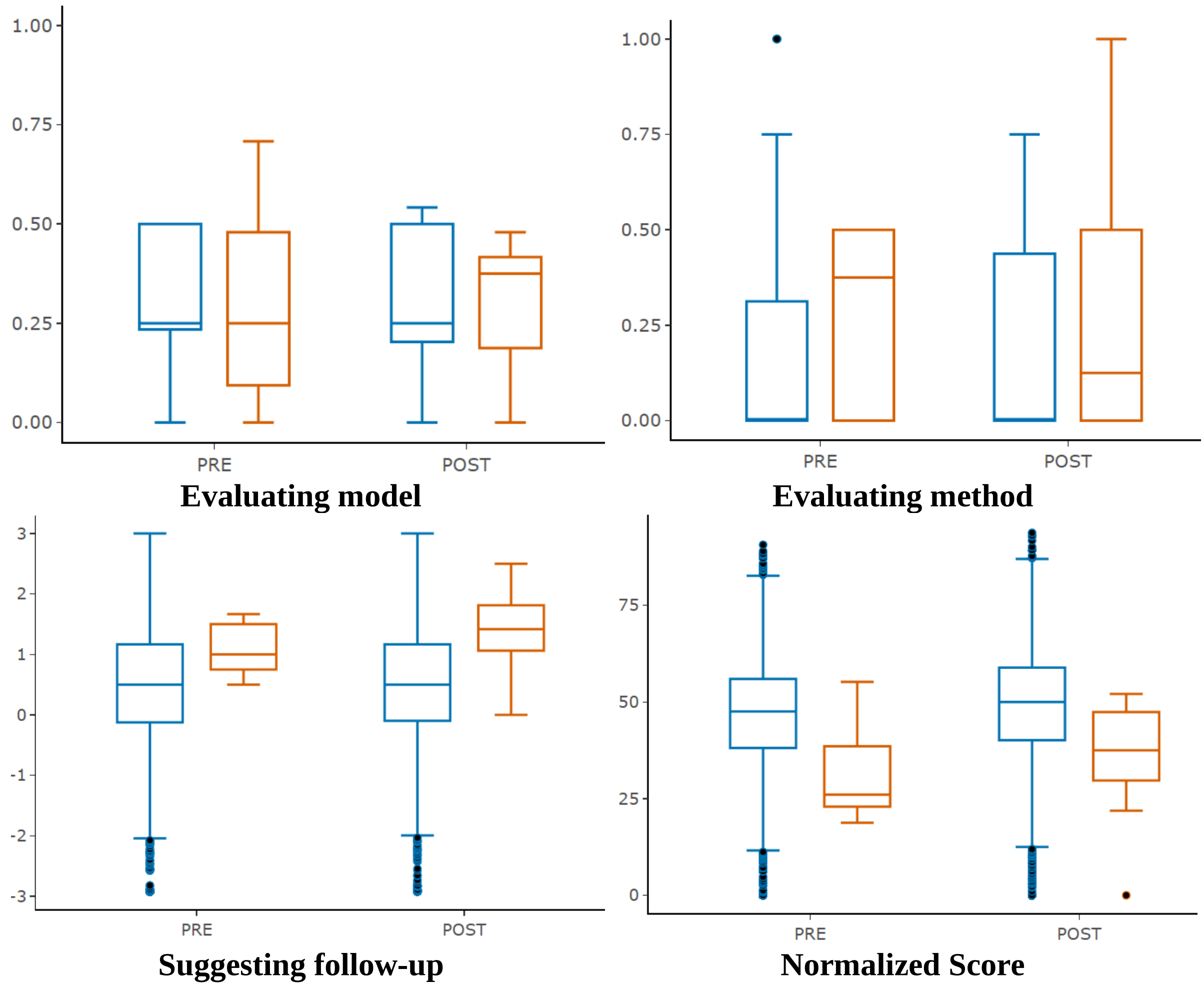

Figure 3. Comparison of factor scores and total scores of students' experimental group and students' control group who have taken the PLIC
Annotation: The orange rectangle represents the experimental group; The blue rectangle represents the control group. The whiskers represent the range of pre-service teachers scores, while the lower and upper quartiles enclose the box. The median score is marked as a horizontal line inside the box and outliers.

From Figure 3, regarding all four scales: *evaluating model*, *evaluating method*, *suggesting follow-up and normalized score*, the post-test PLIC median score for the control group remains unchanged. The median score for both evaluating the model and suggesting follow-up is 0.25. The median score for the evaluating method is 0.00. The normalized score decreases from 44 to 41 (see Table 6). However, the post-test PLIC median score of the evaluating model, suggesting follow-up and normalized score for the experimental group has increased compared to the pre-test PLIC. The results of the post-test PLIC have increased significantly for the experimental group. The results show that the pre-service teachers' experimental competency has improved in the experimental group. Therefore, it can be inferred that inquiry-based laboratories positively affect the development of pre-service teachers' experimental competency.

Table 6 – The median of the evaluating model, evaluating method, suggesting follow-up, and normalized score for the experimental group and control group

Median	Experimental group		Control group	
	Pre-test	Post-test	Pre-test	Post-test
Evaluating models	0.25	0.38	0.25	0.25
Evaluating method	0.38	0.13	0.00	0.00
Suggesting follow-up	1.00	1.42	0.50	0.50
Normalized score	26.00	37.50	44.00	41.00

The result of ECT

As seen in Table 7, the mean score of the post-test ECT of pre-service teachers' experimental competency is higher than the pre-test, which shows that there is a difference between the pre-test and post-test of the pre-service teachers in the experimental group, and the difference is positive for the post-test ($t=-3.920$, $p<.05$). The results of the post-test ECT increased, which demonstrates the effectiveness of IBL for developing pre-service teachers' experimental competency.

Table 7 - The t-test comparison of pre-and post-test results of the ECT of pre-service teachers in the experimental group (consisting of G1 and G2)

	N	*M*	*SD*	*SE*	*t*	*p*
Pre-test	31	3.752	1.409	0.253	-3.920	.000*
Post-test	31	5.197	1.231	0.221		

(*p< .05)

Annotation: only 1 pre-service teacher did not complete the tests

However, regarding the results of the control group, the mean score of the pre-test ECT of pre-service teachers' experimental competency is 5.2, and the post-test average is 4.2 (see Table 8). The mean score of the post-test ECT decreased to 4.2 (lower compared to the experimental group). Moreover, as seen in table 8, it shows that there is no statistical difference between the pre and post-tests of the pre-service teachers in the control group, and it is negative for the post-test ($t=1.783$, $p=.694>.05$). Obviously, the control group did not undergo IBL, thus the results declined, and the per-service teachers' experimental competency did not improve.

Table 8 - The t-test comparison of pre-and post-test results of the ECT of pre-service teachers in the control group (G3)

	N	*M*	*SD*	*SE*	*t*	*p*
Pre-test	10	5.200	1.090	0.345	1.783	.694**
Post-test	10	4.200	1.989	0.629		

(**p> .05)
Annotation: 4 pre-service teachers did not complete the tests

In summary, it is shown from the above results that IBL enhanced pre-service teachers' experimental competency. When the data analysis of the pre-service teachers' PLIC and experimental competency test are examined, it is seen that the inquiry-based laboratories are effective in developing the experimental competency of the pre-service teachers.

The second new result answered research question 2

We have evaluated the level of pre-service teachers' experimental competency development based on the spider web diagram and survey results from Google Forms.

Based on Figure 4, the sub-competences that pre-service teachers have developed the most are: *"Determine the purpose of the experiment"* and "*Set-up and conduct the experiment"*. The highest mean score of the sub-competence "*Determine the purpose of the experiment"* is 2.9, next the second highest mean score of the sub-competence "*Set-up and conduct the experiment"* is 2.64. However, the least developed sub-competence is "*Process data and analyze, evaluate the results"*, in which the mean score is 2.32.

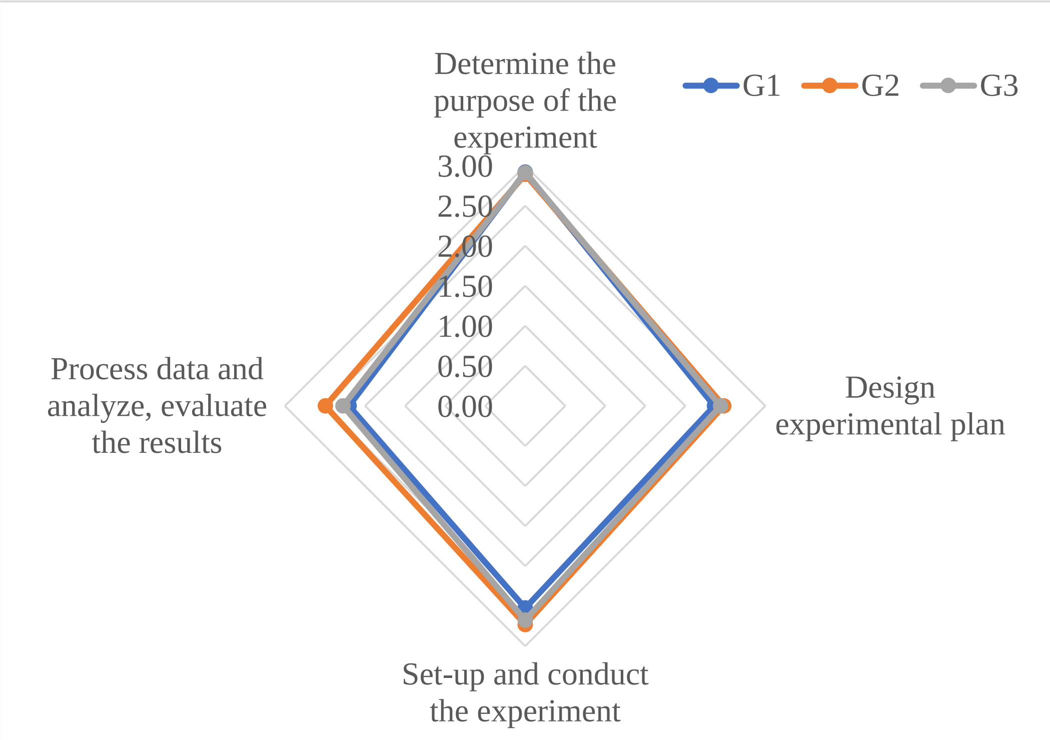

Figure 4. Spider web charts of sub-competences in experimental and control group. Spider web tool to summarise pre-service teachers' experimental competencies

Annotation: G1 and G2 are the experimental groups; G3 is the control group.

Table 9 - Results of assessing the developmental level of behavioral indicators of the experimental and control group

Behavioral indicator	1.3	2.1	2.2	2.3	2.4	2.5	2.7	3.1	3.2	3.3	3.4	4.1	4.2	4.3	4.4	4.5
G1	2.92	2.91	2.75	2.37	2.15	2.53	1.47	2.58	2.45	2.51	2.55	2.44	2.19	2.41	2.18	1.78
G2	2.89	2.90	2.75	2.63	2.67	2.63	1.30	2.73	2.65	2.81	2.74	2.79	2.75	2.73	2.35	1.85
G3	2.91	2.79	2.79	2.57	2.57	2.57	1.36	2.78	2.70	2.58	2.64	2.59	2.43	2.34	2.23	1.78
Mean	**2.91**	2.87	2.76	2.52	2.46	2.58	**1.38**	2.70	2.60	2.63	2.64	2.61	2.46	2.49	2.25	1.80

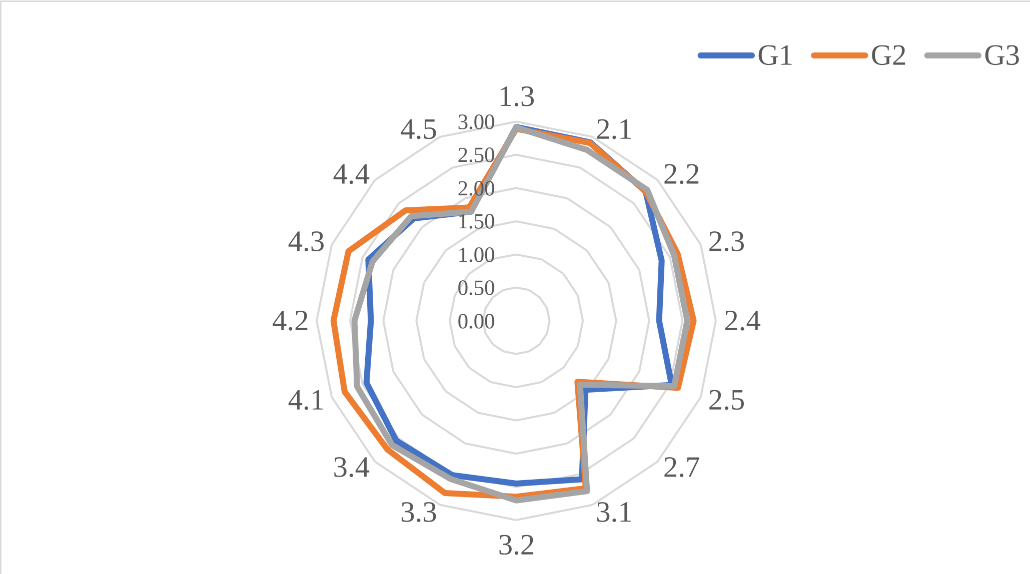

Figure 5. Spider web charts of behavioral indicators in experimental and control group

As seen in Figure 5, the spider web diagram should be concave at behavioral indicators 2.7 and 4.5, which are the least developed behavioral indicators. The spider web diagram should be pointed at behavioral indicators 1.3; 2.1; 2.2; and 3.1, which are the most developed behavioral indicators. Combined with the data in Table 9, we see that behavioral indicator 1.3 has the highest mean score of 2.91 and behavioral indicator 2.1 has the second highest mean score of 2.87. However, behavioral indicator 2.7 has the lowest mean score of 1.38, followed by behavioral indicator 4.5, with the second lowest score of 1.80.

The results in Figure 4, Figure 5, and Table 9 are obtained from the surveys using Google Forms, which show that:
+ 57.1% of pre-service teachers think that behavioral indicator 2.7 (Propose ideas to improve experimental equipment) is developed the least for 5 main reasons. Firstly, the improvement of laboratory equipment is difficult since pre-service teachers are less interested in other experimental equipment outside the laboratory. Secondly, the pre-service teachers do not understand the data processing method and cannot imagine how to improve the instruments, for it is still based on the existing template. Thirdly, pre-service teachers have not yet started to do other experiments. Pre-service teachers always use available experimental methods. Pre-service teachers do not understand the true meaning of each instrument and the steps to do the experiment. Fourthly, the study time and conditions to have the necessary experimental equipment were not enough. Finally, if the measurement error is within the allowable range, they will not need to improve the experimental instrument.

+ There are three main reasons why 71.4% of pre-service teachers believed that behavioral indicator 1.3 (Determining the purpose of the experiment) is the most developed. Determining the purpose of the experiment is a necessary condition for doing an experiment. Next, in the process of learning experiments, pre-service teachers always interact directly with the experiment, making it easy to draw knowledge from observation. Finally, the behavioral indicator was performed multiple times in the experiments and was found to be similar.

❖ **The level of pre-service teachers' experimental competency development after taking this course**

Table 10- Statistics of pre-service teachers reaching behavioral level 1, level 2, level 3

	Level 1	**Level 2**	**Level 3**
Experimental group	0%	85.37%	14.63%
Control group	14.29%	78.57%	7.14%

The results obtained from Table 10:
In the experimental group, 85.37% of pre-service teachers achieved level 2 while Table 10 in the control group was only 78.57%. 14.63% of pre-service teachers achieved level 3 (compared to only 7.14% in the control group). None of the students achieved level 1.

In the control group, 14.29% of pre-service teachers were still at level 1; 78.57% of pre-service teachers were at level 2 and 7.14% of pre-service teachers achieved level 3.

Overall, the percentage of pre-service teachers reaching level 3 is still low in both groups, since achieving level 3 is slightly difficult for pre-service teachers.

Conclusion

In this article, the authors found two new results. The results shed light on the positive impact of IBL on developing pre-service teachers' experimental competency. The first result evaluated the effectiveness of IBL for the General Physics Laboratory course. IBL enhanced pre-service teachers' experimental competency. The second result is the development level of pre-service teachers' behavioral indicators in the experimental competency framework. 14.63% of pre-service teachers achieved behavioral level 3, and 85.37% of pre-service teachers achieved behavioral level 2. The research results show that the most developed behavioral indicators were (1.3) Determine the purpose of the experiment; (2.1) Determine the experiment instruments to be used and the least developed behavioral indicators were (2.7) Propose ideas to improve experimental equipment; (4.5) Propose measures to reduce error. However, the sample size is relatively small, which highlights a possible line of future research to implicate IBL in experimental courses with a wider research scope and a larger sample size.

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