Developing of Experimental Competence of Laos Pupils in Secondary School Science Classroom

Van Bien NGUYEN1, Xayparseut, VYLAYCHIT & Anh Thuan NGUYEN

Received: 7 July 2019  Accepted: 20 August 2019

Abstract

How to help teachers to design teaching plan for raising student’s competency at secondary school in Laos is now of great concern. On the other hand, teachers teach sciences almost by lecturing theoretical only. They rarely explain the problems based on actual phenomena that occur in pupils’ daily life nor do experiment during the class. Thus, one of the vital concerns for Lao’s science education is that the summative and formative assessment for science learning are both only focused on evaluating the pupils’ knowledge. To develop experimental competence, we developed and evaluated a practical science course “Heat and temperature” with hands on activities and realistic application, using action research approach. For measuring experimental competence, the framework for practical assessment from some previous researchers was adapted and used. In this paper, we describe the process and experiences of how to develop the course with comprehensive worksheets and hands on equipment. We also interpret the way to gather evidence of experimental competence during the course. As a result, the course with hands-on activities and realistic application can significantly develop the following indicators of experimental competence: “Make logical reasoning to find out what to investigate”, “Identify which physics quantity should be measured or which phenomena should be observed”, “Describe experimental design”, “Collect experimental data”, “Interpret experimental data”.

Keywords:
experimental competence, Lao pupils, head and temperature

To cite this article:

1 Hanoi national university of education, Hanoi, Vietnam, E-mail: biennv@hnue.edu.vn ORCID No: 0000-0001-9540-6342
Introduction

Experiment is very important in teaching and learning physics, which is concluded from many literature. Millar (2004) defined practical work as any teaching and learning activity which involves the students to observe and manipulate real objects and materials. Practical work enables the students to act in a scientific manner (Millar, 2004), and these science practices need to consider everyday-life problems (Muhlisin, Susilo, Amin, & Rohman, 2018). According to Josephy (1986), an assessment of practical and experimental work in physics through OCEA include 4 processes, namely Planning (Designing experiments; raising and clarifying problems); Performing (observing, manipulating, data gathering); Interpreting (data handling, making inferences, predicting and explaining); Communicating (reporting, receiving information). No hierarchy or sequence is implied by presenting the processes and skills in this particular order (Josephy, 1986).

Unfortunately, the earlier researchers have found that the practical activities in the school are not achieving the required objectives due to insufficient learning strategies (Muhlisin, 2019). The results of Lin Zang’s research showed that the instructional conditions affected students' learning of energy transfer in knowing and reasoning, but not in applying. After test students' prior knowledge, participants in the hands-on inquiry condition gained less class content and demonstrated a lower ability of reasoning than those in the direct instruction condition (Zhang, 2018). These negative results of practical work ask us to rethink about the objectives of laboratory work. Van Driel et al. observed in their research study that the prior efforts towards improving teachers’ practical knowledge failed because it did not take into account the teachers’ existing knowledge, beliefs and attitudes (Van Driel, Beijaard, & Verloop, 2001). According to Woolnough, practical work is not finding due emphasis in the schools in developing countries (Miller & Kastens, 2018). This status quo is still a current situation of science education in Laos and some other ASEAN countries.

There are a lot of research about pupils’ achievement assessment. The conception of experimental competency still has various meanings. The experimental process will further activate students in learning so that student learning achievement increases (Muhlisin et al., 2018). Some research from native English researchers interpret this conception as practical skills. Others consider practical abilities as an element of “scientific abilities” for the same meaning (E. Etkina, Van Heuvelen, Brookes, & Mills, 2002). Some research from EU see the experimental competency be the meaning of pupils ability about doing experiments(Metzger, Gut, Hild, & Tardent, 2014), (Schecker, Neumann, Theyßen, Eickhorst, & Dickmann, 2016). These various are shown in table 1. In this table, we can find some differences between content of conception from previous researchers.

We can recognize that the conceptions of researcher is quiet similar. In this study, we use some of skills from previous researchers to construct indicative behaviors of
experimental competence. We develop the levels-quality criteria for each indicative behaviors. It could be help teacher design their lesson plan for raising experimental competence.

Table 1
Conception of Some Authors about Experimental Competence

<table>
<thead>
<tr>
<th>Authors</th>
<th>OCR(OCR, 2018)</th>
<th>Etkina(1)</th>
<th>Metzger (2)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Conception</td>
<td>Practical Skills</td>
<td>Scientific abilities</td>
<td>Experimental competence</td>
</tr>
<tr>
<td>Definition</td>
<td>Non</td>
<td>to describe some of the most important procedures, processes, and methods that scientists use when constructing knowledge and solving experimental problems.</td>
<td>refers only to problems with an authentic hands-on interaction, involving scientific questions as well as engineering tasks</td>
</tr>
</tbody>
</table>

Indicator; elements; sub – skill;

(a) apply investigative approaches and methods to practical work
(b) safely and correctly use a range of practical equipment and materials
(c) follow written instructions
(d) make and record observations and measurements
(d) make and record observations and measurements
(e) keep appropriate records of experimental activities
(f) present information and data in a scientific way
(g) use appropriate software and tools to process data, carry out

A. the ability to represent physical processes in multiple ways;
B. the ability to devise and test a qualitative explanation or quantitative relationship;
C. the ability to modify a qualitative explanation or quantitative relationship;
D. the ability to design an experimental investigation;
E. the ability to collect and analyze data;
F. the ability to evaluate experimental predictions and outcomes

categories conducted observation, measurement with a given scale, scientific investigation, experimental comparison, constructive problem solving
In this study, it is defined the conception of experimental competence with the meaning “the ability to meet a complex demand successfully or carry out a complex activity or task” from Weinert (Weinert, 2001). We define experimental competence refer to the ability to gather knowledge, skills, attitudes to do experiment successfully. With this meaning, according to framework of competence constructed from Woods and Griffin (Woods & Griffin, 2013), (Griffin, McGaw, & Care, 2012), the experimental competence is constructed in 4 capabilities; and 10 indicative behaviors. (table 2).

Table 2:
Framework of Experimental Competence

<table>
<thead>
<tr>
<th>Capability</th>
<th>Indicative behaviour</th>
<th>Levels - Quality criteria</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.Identify purpose of</td>
<td>Ex1.1.Make logical reasoning to find out</td>
<td>Level 1: Make simple reasoning about a physicsquantity with popular phenomena to identify what to investigate</td>
</tr>
<tr>
<td>experiment</td>
<td>what to investigate</td>
<td>Level 2: Make reasoning about two physics quantities with popular phenomena to identify what to investigate</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Level 3: Make reasoning about two physics quantities with new phenomena to identify what to investigate</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Level 4: Make reasoning about complex new phenomena to identify what to investigate</td>
</tr>
<tr>
<td>Ex 1.2. Identify which physics quantity should be measured or which phenomena should be observed</td>
<td>Level 1: Identify a physics quantity to be measured related to simple observed phenomena</td>
<td></td>
</tr>
<tr>
<td>Level 2: Identify physics quantities to be measured related to simple observed phenomena</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Level 3: Identify physics quantities to be measured related to popular new observed phenomena</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Level 4: Identify physics quantities to be measured related to complex new observed phenomena</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

| Ex 2.1. Choose equipment to make measurement | Level 1: Choose a equipment to make simple measurement |
| Level 2: Choose equipment to make measurement with two quantities |
| Level 3: Choose and adapt equipment to make measurement with two quantities |
| Level 4: Choose and adapt equipment to make complex measurement |

| Ex 2.2. Describe experimental design | Level 1: Describe experimental design with single measurement |
| Level 2: Describe experimental design with two measurement |
| Level 3: Describe complex experimental design |
| Level 4: Describe complex experimental design in optical way |

| Ex 3.1. Identify real equipment to make measurement | Level 1: Identify popular equipment for simple measurement |
| Level 2: Identify popular equipment for normal measurement |
| Level 3: Identify and choice right equipment for measurement from experimental set |
| Level 3: Identify and choice right equipment for measurement from complex experimental set |

| Ex 3.2. Use available equipment to construct measurement | Level 1: Use available equipment to construct simple measurement |
| Level 2: Use available equipment to construct complex measurement |
| Level 3: Construct new equipment to make simple measurement |
| Level 4: Construct new equipment to make complex measurement |
### 3. Collect Experimental Data

**Level 1:** Collect some single experimental data

**Level 2:** Collect series single experimental data of one quantity

**Level 3:** Collect some series experimental data from independent variables

**Level 4:** Collect some series experimental data from dependent variables

### 4. Analyse and Interpret Experimental Data

**Ex 4.1. Analyse Experimental Data**

**Level 1:** Analyse, identify the experimental error

**Level 2:** Analyse, identify and explain the experimental error

**Level 3:** Analyse, identify, explain the experimental error and suggest method to reduce error

**Level 4:** Analyse, identify, explain the experimental error and suggest and test the method to reduce error

**Ex 4.2. Interpret Experimental Data**

**Level 1:** Interpret results of the experiment and make a simple conclusion

**Level 2:** Interpret and make a judgment about the results of the simple experiment

**Level 3:** Interpret results of the experiment and make a complete conclusion

**Level 4:** Interpret and make a judgment about the results of the simple experiment with complete conclusion

**Ex 4.3. Evaluate and Identify Shortcomings in an Experimental Design and Suggest Specific Improvements**

**Level 1:** Evaluate process of experiment and identify a improvable step

**Level 2:** Evaluate process of experiment and identify improvable steps

**Level 3:** Evaluate process of experiment, identify improvable steps and suggest specific improvements

**Level 4:** Evaluate process of experiment, identify improvable steps; suggest and do specific improvements

In this study, our research questions the followings:

Do students develop experimental competence during the heat and temperature course?

Is the framework of experimental competence suitable with real learning context of Laos school?
Which pupils’ indicative behaviour of experimental competence can be developed?

**Method**

**Theoretical Framework**

We use construct of experimental competence for teaching and learning process and for assessment the experimental competence of pupils. The framework can be drawn in to a model like Figure 1.

![Diagram](image)

**Figure 1:**

*Process of teaching and learning for development of pupil experimental competence*

**Design of the heat and temperature course**

The course “Heat and temperature” is a part of grade 8 science curriculum. In both curriculum and textbook, the aim of developing experimental competence is not clearly written. Within our framework, we develop the experimental course with 8 lessons,

*Lesson 1: Heat and temperature*
Lesson 2: Heat conduction
Lesson 3: Quantity of heat
Lesson 4: Heat equation
Lesson 5: Heat of combustion
Lesson 6: Mechanical equivalent of heat
Lesson 7: Heat engines

The physics education research uses summative assessment tools that tell us whether students have mastered the concepts of Newton’s laws, thermodynamics, electricity and magnetism to solve physics problems. Physics by Inquiry, Workshop Physics, use a formative assessment of student learning in the process of learning, but their focus is also mostly about conceptual understanding. Some new recent research such as ExKoNawi (Gut, Metzger, Hild, & Tardent, 2014); Design lab (Eugenia Etkina & Murthy, 2006) focus on experimental competence during solving experimental problems. In each lesson, we develop tasks using experiment in three ways: observational experiment, testing experiment, and application experiment (E. Etkina et al., 2002). Some tasks with hands on experiments can be prepared at home by pupils. Each experimental task is developed in the same physical scenario. It is easy for us to assess the pupils’ indicative behaviour of experimental competence. We use rubrics based on construct of experimental competence with difference levels. Below are two sample tasks.

Task 2.1 Heat conduction

Question: Does every metal conduct heat the same? Which metal is the best of heat conduction material?

Experimental design (see Figure 2): We use 3 rods of 3 metals: aluminium, iron, copper. Rods have the same shape and size. Some small nails are glued with candle wax on each rod with equal positioning distances. Put the burner right below the intersection of the three rods and observe the result. Explain the experimental outcome and make a conclusion.

Figure 2
Experiment heat conduction
Task 5.2. Heat of combustion from difference fuels

Question: Which fuels emit more heat energy: petroleum, alcohol or wax candle?

Which quantities does the heat of combustion of a fuel depend on?

Experimental design (see Figure 3): we measure indirectly emitted heat by using the equation: \( Q = mc\Delta T \), \( m \) is mass of water inside the coke, \( c \) is specific heat of water, \( \Delta T \) is temperature change.

Burn the same mass of different fuels and compare the increasing of temperature of the water inside dose. The results can tell us the answer of the question.

![Figure 3: Heat of combustion](image)

Table 3.
Rubrics for assessing experimental competence for these two tasks:

<table>
<thead>
<tr>
<th>Indicative behaviour</th>
<th>Level 1 (1 point)</th>
<th>Level 2 (2 points)</th>
<th>Level 3 (3 points)</th>
<th>Level 4 (4 points)</th>
<th>Point of pupil</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ex 1.2. Identify which physics quantity should be measured or which phenomena should be observed</td>
<td>Identify one quantity as independent variables</td>
<td>Identify two quantities as independent variables</td>
<td>Identify all quantities as independent variables and dependent variables</td>
<td>Identify all quantities as independent variables and dependent variables with critical explain</td>
<td></td>
</tr>
<tr>
<td>Ex 2.2. Describe experimental design</td>
<td>Rewrite experimental design</td>
<td>Draw and write a part of experimental design</td>
<td>Draw and write complete experimental design</td>
<td>Draw and write complete creative experimental design</td>
<td></td>
</tr>
<tr>
<td>Ex 3.3. Collect experimental data</td>
<td>Collect single data</td>
<td>Collect some data from experiment</td>
<td>Collect all series of data</td>
<td>Collect all series of data and filter invalid data</td>
<td></td>
</tr>
</tbody>
</table>
Developing of experimental …

<table>
<thead>
<tr>
<th>Ex 4.1. Analyse experimental data</th>
<th>Compare two single data</th>
<th>Compare data directly</th>
<th>Compare series of data by using graph</th>
<th>Compare series of data by using calculus and graph</th>
</tr>
</thead>
</table>

Other similar rubrics of remaining indicative behaviours are prepared for other tasks too. To prove the hypothesis of developing experimental competence during practical courses, we repeat every lesson with all of the indicators from table 1. The research timeline can be drawn as Figure 4.

![Timeline of teaching and learning; assessment of Heat and temperature course](image)

**Figure 4:**
*Timeline of teaching and learning; assessment of Heat and temperature course*

**Evaluation of the heat and temperature course**

In order to evaluate the effectiveness of this course, we select the sample of 49 pupils in grade 8 at average level of cognitive ability and study conditions in Laos PDR. Data collection: We collected the evidence of indicative behaviours during learning process by collecting all worksheets of students and observing classroom video footage (see Figure 5). For each task, we can determine how many pupils reach the described levels of indicative behaviours. On the other hand, we can also see how change the levels of pupil's indicative behaviours over the time.
Figure 5
Worksheet of Pupil for Assessment

Data Analysis and results: To answer the first research question, we collect a table of levels of all indicative behaviours (IB) in every task (see table 4) for each pupil. From these tables, we observe the raising of levels experimental competence of pupils.

Table 4.
Results of Levels of One Pupil’s Indicative Behaviours

<table>
<thead>
<tr>
<th>Task</th>
<th>Indicative behaviours</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>IBE x1.1</td>
</tr>
<tr>
<td>Task 1.1</td>
<td>1</td>
</tr>
<tr>
<td>Task 1.2</td>
<td>1</td>
</tr>
<tr>
<td>Task 2.1</td>
<td>2</td>
</tr>
<tr>
<td>Task 2.2</td>
<td>1</td>
</tr>
<tr>
<td>Task 3.1</td>
<td>3</td>
</tr>
<tr>
<td>Task 3.2</td>
<td></td>
</tr>
<tr>
<td>Task 3.3</td>
<td></td>
</tr>
</tbody>
</table>
From this table we can draw the development of each indicative behaviour from these pupils. We can not determine every indicative behaviors in every single task, but only during each lesson (Figure 6).

**Figure 6:**
*Development of Experimental Competence One Pupil*

From the Figure 6, we can recognize the tendency of increasing indicative behavior levels of this pupil. Gathering all the data about experimental competence of all 49 pupils, we can answer the other research questions and conclude that:

Some indicative behaviors of pupils are clearly increased such as Ex 1.1. Make logical reasoning to find out what to investigate; Ex 1.2. Identify which physics quantity should be measured or which phenomena should be observed; Ex 2.2. Describe experimental design; Ex 3.3. Collect experimental data; Ex 4.2. Interpret experimental data. Other indicators are needed more time and effort to prove.

<table>
<thead>
<tr>
<th>Task</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>3</th>
</tr>
</thead>
<tbody>
<tr>
<td>4.1</td>
<td>3</td>
<td>2</td>
<td>3</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>4.2</td>
<td>2</td>
<td>3</td>
<td>3</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>5.1</td>
<td>2</td>
<td>3</td>
<td>2</td>
<td>3</td>
<td></td>
</tr>
<tr>
<td>5.2</td>
<td>3</td>
<td>3</td>
<td>2</td>
<td>4</td>
<td>3</td>
</tr>
<tr>
<td>6.1</td>
<td>3</td>
<td>3</td>
<td>3</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>6.2</td>
<td>3</td>
<td>3</td>
<td>3</td>
<td>3</td>
<td>3</td>
</tr>
<tr>
<td>7.1</td>
<td>3</td>
<td>3</td>
<td>4</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>7.2</td>
<td>3</td>
<td>3</td>
<td>4</td>
<td>3</td>
<td>3</td>
</tr>
</tbody>
</table>
Conclusion

The framework of teaching and learning for development of pupil experimental competence, including the suggested construct of experimental competence prove to be helpful for designing competence-based education (CBE) courses. Through such short CBE course of 07 periods, the more mind-on indicators like “Make logical reasoning to find out what to investigate”, “Identify which physics quantity should be measured or which phenomena should be observed”, “Describe experimental design”, “Interpret experimental data” are more likely developed. It seems that the more hands-on indicators of experimental competence take more time.

Biodata of the Authors

**Dr. Van Bien NGUYEN** was born in Hanoi, Vietnam. He is a Lecturer of Physics education at the Hanoi national University of Education. He received his undergraduate degree from Hanoi national University of Education and his Ph.D. in physics education from University of Koblenz Landau (Germany) in 2007. He has been at the from Hanoi national University of Education ever since 2001, and served as Vice Dean of the Faculty of Physics there from 2012. His current research effort is devoted entirely to physics education at high school level and the college level. He gave lecturers “Physics high school curriculum analysis”, “Assessment in physics education” and “ICT in physics education” for Bachelors and Master in Physics education. **Affiliation:** Hanoi national university of education, Hanoi, Vietnam  
**E-mail:** biennv@hnue.edu.vn  
**Phone:** +84983528399

**Xayparseut VYLAYCHIT** was born in Salavan, Laos. He is a doctoral of physics education at the Hanoi national University of Education.  
**Affiliation:** Salavan Teacher Trainning College, Laos, Vietnam.  
**E-mail:** vxayparseut@yahoo.com  
**Phone:** +84334047020

**Dr. NGUYEN Anh Thuan** was born in Laocai, Vietnam. He is a Lecturer of Physics education at the Hanoi national University of Education. His current research effort is devoted entirely to physics education at high school level and the college level. He gave lecturers “Demonstration experiment in physics teaching” and “ICT in physics education” for Bachelors and Master in Physics education.  
**Affiliation:** Hanoi national university of education, Hanoi, Vietnam  
**E-mail:** thuanna@hnue.edu.vn  
**Phone:** +84912777205
References


