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Research Article

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

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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

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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), a ssessment 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

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

	research and report findings (h) use online and offline research skills including websites, textbooks and other printed scientific sources of information (i) correctly cite sources of information use a wide range of experimental and practical instruments, use equipment and techniques appropriate to the knowledge and understanding included in the specification	

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

Capabilitiy	**Indicative behaviour**	**Levels - Quality criteria**
1.Identify purpose of experiment	Ex1.1.Make logical reasoning to find out what to investigate	Level 1: Make simple reasoning about a physicsquantity with popular phenomena to identify what to investigate
		Level 2: Make reasoning about two physics quantities with popular phenomena to identify what to investigate
		Level 3: Make reasoning about two physics quantities with new phenomena to identify what to investigate
		Level 4: Make reasoning about complex new phenomena to identify what to investigate

	Ex 1.2.Identify which physics quantity should be measured or which phenomena should be observed	Level 1: Identify a physics quantity to be measured related to simple observed phenomena
		Level 2: Identify physics quantities to be measured related to simple observed phenomena
		Level 3: Identify physics quantities to be measured related to popular new observed phenomena
		Level 4: Identify physics quantities to be measured related to complex new observed phenomena
2. Design an experimental investigation	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
3. Do experiment	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

	Ex 3. 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

Theorical 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.

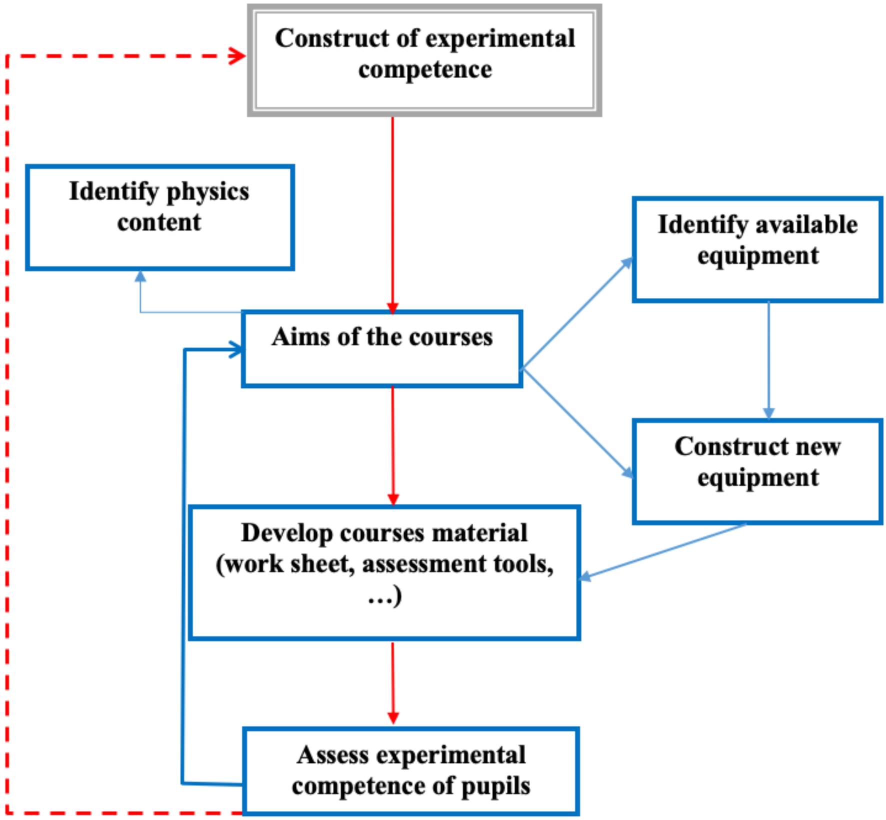

Figure 1.
Process of teaching and learning for development of pupil experimental competence

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 assessmenttools that tell us whether students have mastered the concepts of Newton's laws, thermodynamics, electricity andmagnetism to solve physics problems. Physics by Inquiry, Workshop Physics, use a formative assessment of student learning inthe 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 gluedwith 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, ΔT 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

Table 3.
Rubrics for Assessing Experimental Competence for These Two Tasks

Indicative behaviour	Level 1 (1 point)	Level 2 (2 points)	Level 3 (3 points)	Level 4 (4 points)	Point of pupil
Ex 1.2. Identify which physics quantity should be measured or which phenomena should be observed	Identify one quantity as independent variables	Identify two quantities as independent variables	Identify all quantities as independent variables and dependent variables	Identify all quantities as independent variables and dependent variables with critical explain	
Ex 2.2. Describe experimental design	Rewrite experimental design	Draw and write a part of experimental design	Draw and write complete experimental design	Draw and write complete creative experimental design	
Ex 3. 3. Collect experimental data	Collect single data	Collect some data from experiment	Collect all series of data	Collect all series of data and filter invalid data	
Ex 4.1. Analyse experimental data	Compare two single data	Compare data directly	Compare series of data by using graph	Compare series of data by using calculus and graph	

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.

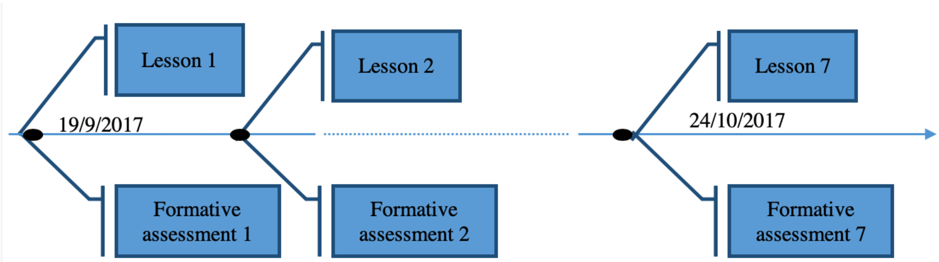

Figure 4.
Timeline of Teaching and Learning; Assessment of Heat and Temperature Course

Evaluation of the Heat and Temperature Course

In oder 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 collectedthe 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 theother hand, we can also see how change the levels of pupil's indicative behaviours over the time.

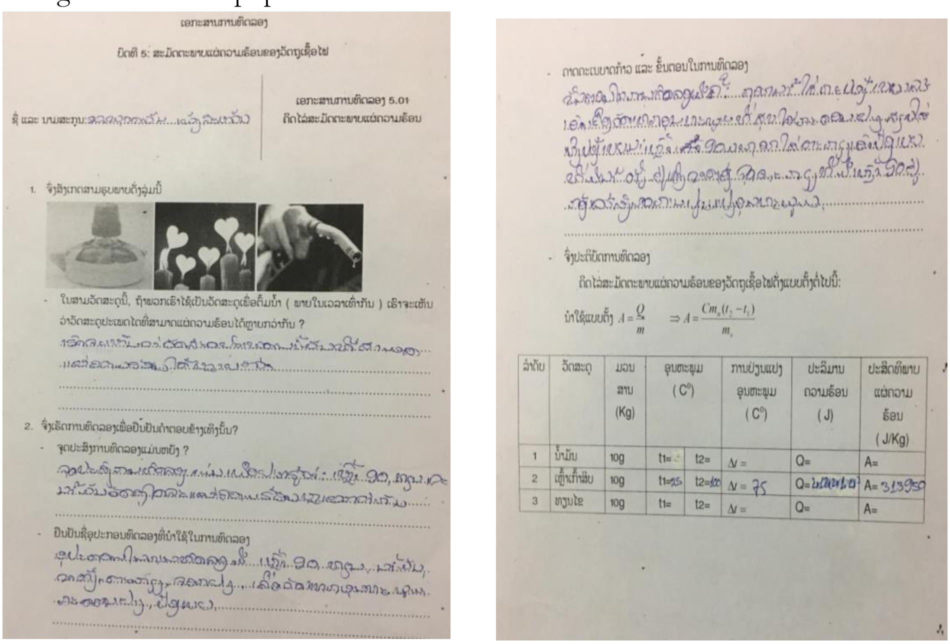

Figure 5.
Worksheet of Pupil for Assessment

Data Analysis and results: To answer the first reseach 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 obserb the raising of levels experimental competence of pupils.

Table 4.

Results of Levels of One Pupil's Indicative Behaviours

Task	Indicative behaviours									
	IBEx1.1	IBEx1.2	IBEx2.1	IBEx2.2	IBEx3.1	IBEx3.2	IBEx3.3	IBEx4.1	IBEx4.2	IBEx4.3
Task 1.1	1	1	2	1	1			1		
Task 1.2		1	2			1	1		1	1
Task 2.1		2		2			2	2		
Task 2.2.	1	2	2	2	2	2			1	1
Task 3.1	3	2	3	1				2		
Task 3.2				3	2	2		3		
Task 3.3	3	2		3			3	3	3	3
Task 4.1	3	2		3		3		4	3	
Task 4.2	2	3	3		2		3	4		3
Task 5.1		2		3			2	3		
Task 5.2	3			3	3	2	4	3	2	3
Task 6.1	3	3	3	3			2	3	3	
Task 6.2.		3			3	3			3	3
Task 7.1	3			3	4	3		4		3
Task 7.2	3	3	3	4		3	3	3	3	4

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).

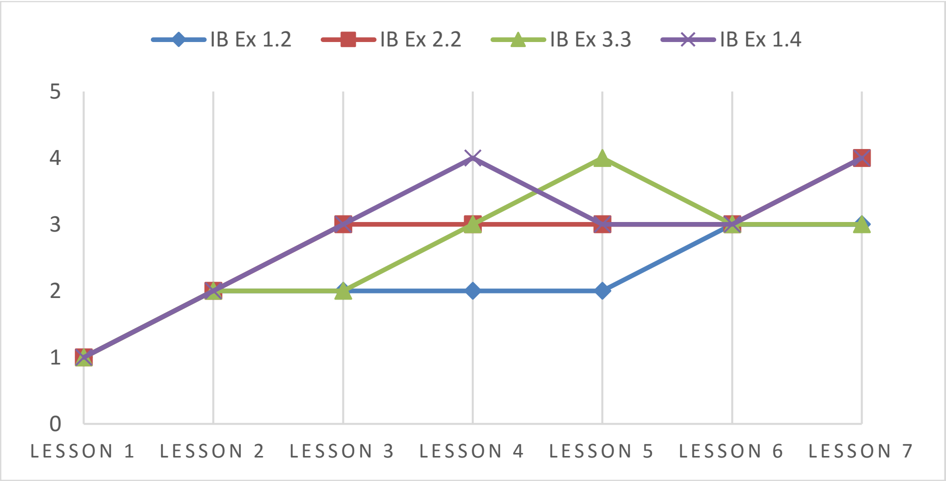

Figure 6.
Development of Experimental Competence One Pupil

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.

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.

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