EXPLORING TERTIARY STUDENTS' CONCEPTION OF HEAT AND TEMPERATURE

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ABSTRACT

This study employs the survey, the Heat and Temperature Conceptual Evaluation (HTCE), to study the understanding of thermal physics of a group of some 200 introductory physics students at the Ubon Ratchathani University. The classes was administered the HTCE survey for pre-instruction. The overall objective of the study was to determine if the HTCE survey can reliably gauge students' conception. The pre-test scores and gender were considered as possible influences on student responses to the survey. We find that the HTCE survey can reliably gauge students' conception and the basic conceptual areas of specific heat capacity and change of phase were particularly difficult for the students. There is a statistically significant difference between females and males in the pre-test mean score.

Keywords : Heat and Temperature Conceptual Evaluation (HTCE) survey, Tertiary students' conception

Introduction

For the last two or three decades, one of the main thrusts among researchers in tertiary science education has been the study of student conception. Particularly among physics education researchers, the agenda has been to learn to recognize when students hold conceptions which differ from those of expert physicists (in which case they are often termed "misconceptions"), to develop instruments to detect when students hold these misconceptions, and to propose teaching strategies to align student conceptions closer to the mainstream. See for example Confrey (1990), Christianson and Fisher (1999), and Duit and Treagust (1998).

Such studies have led to learning and teaching environments within the constructivist framework aiming to support conceptual change. A critical requirement is that teachers should be able to gauge reliably what conceptions their students hold. Strategies generally used in schools include talking with small groups of students, or asking them to write explanations (Ali, 2002; Geraedts & Boersma. 2006). However, in higher education and for comparative studies, conceptual surveys seem to have become the instrument of first choice (McDermott & Redish. 1999), and we note that some of the more widely used conceptual surveys have been translated into several languages, facilitating international dialogues on students' conception (Evaluation Instruments. 2007).

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The area of heat and temperature is important at an introductory level, because it underpins physics and chemistry. It relates to everyday, tangible ideas and is covered across several years of instruction in both high school and university education. This paper describes a study of understandings of thermal physics for undergraduate physics students in Thailand. The Heat and Temperature Conceptual Evaluation (HTCE) survey was used for this research, an instrument that has been in general use for nearly a decade (Thornton & Sokoloff. 2001).

In Thailand, the Institute for the Promotion of Teaching Science and Technology (IPST) plays an important role in the teaching of science. Based on the 2001 National Curricula in Thailand, the curriculum for Thai high schools is controlled by the IPST. The curricula has been reformed with the intent to improve students' knowledge, thinking process, inquiry thinking skill, problem solving skill, ability of scientific communication, ability of application and scientific attitude (Ministry of Education [MOE]. 2008). In thermal physics, the topics covered in grade 11 physics are heat and temperature, change of phase, specific heat capacity, thermal expansion, heat transfer, Boyle 's law, Charles' law, Louis Gay-Lussac' s law and kinetic theory of gases. Classroom instruction has been reorganized to facilitate students to construct their knowledge themselves and apply their knowledge to explain phenomena in everyday life.

The plan of this study was to investigate students' conceptual understanding of the material before instruction using the HTCE survey. The results of this study may imply the teaching style in Thai high schools that may be problematic. In addition, the students' misconception found could be used as a guide for developing proper teaching methods on the general physics course especially in the topic of thermal physics.

The aims of the study

The purpose of this study was to investigate the students' conceptual understanding held by introductory physics students before instruction using the HTCE survey. The study was plan to find the answers to following the research questions 1) Which concepts in thermal physics are better understood than others for first year students? 2) Are there differences in male and female responses to the survey?

Methodology

In this section we describe the overall design of the study

Conceptual test

Various surveys are available which explore different aspects of students' understandings of thermal physics. For example Yeo and Zadnik (2001) have developed the Thermal Concepts Evaluation Test for investigating student understandings of thermal physics in everyday situations. There is also the Heat and Temperature Concept Evaluation survey developed by Thornton and Sokoloff in 2001, which is designed to uncover key fundamental alternative conceptions. We have chosen to use the latter.

The HTCE survey is a 28 item instrument with 27 multiple choice items and one item (item 24) requiring the drawing of a graph. This item was removed from all our analysis because student responses could not be readily quantified. The survey takes about 40 minutes to complete. For the purposes of our research project, the questions of the HTCE survey have been divided into eight "conceptual areas" (see Table 1).

Table 1: Categories of Conceptual Areas in the HTCE Survey

Code	Conceptual areas	Question Numbers
H&T	Heat and temperature	1, 2, 3, 4
COOL	Rate of cooling	5, 6, 7
CAL	Calorimetry	8, 9
RHT	Rate of heat transfer	10, 11
HOT	Perception of hotness	12, 13, 14, 15
CAP	Specific heat capacity	16, 17, 18, 19
PHASE	Change of phase	20, 21, 22, 23, 25
COND	Thermal conductivity	26, 27, 28

The Thai versions of the HTCE survey

The HTCE survey had first to be translated into the Thai language, and it was important that the translated version should be as reliable as the English version, as closely as possible. Therefore we subjected the results to a reliability analysis, using the standard techniques used with conceptual surveys, described, for example, by Ding, Chabay, Sherwood and Beichner (2006) and Wells and Wollack (2003).

In 2005 the HTCE survey was translated into the Thai language and the translation was checked by a panel of five physicists. Ten Thai physics postgraduate students took the English language version of the HTCE survey and a month later took the Thai language version. Responses were compared using two methods. First, a tally was made of the number of students who gave the same answer in the two versions for each question, irrespective of whether the answer was correct or not. Apart from questions from the conceptual areas *rate of heat transfer* and *specific heat capacity*, at least 73% of the students gave the same answer in both versions. Second, a tally was made of the number of students who gave correct answers for each question in the two versions. Conceptual areas *rate of heat transfer* and *specific heat capacity* were most difficult, and there was evidence to suggest that students were inconsistent in their use of these ideas and tended to switch between concepts. Tao and Gunstone (1999) found similar switching between mechanics concepts by Grade 10 science students, as did diSessa (1996) in in-depth interviews. The ten Thai students scored poorly in the area of *change of phase* in both versions of the survey. Finally, five students were interviewed in Thai with regards to interpretation of the items in the two languages. No language or cultural issues were found biased towards either version.

The reliability and discriminatory of Thai versions of the HTCE survey was evaluated using five standard statistical tests. The first three statistics (item difficulty index, item discrimination index and point biserial coefficient) focus on individual items and the last two (Kuder-Richardson's formula 21 test reliability index and Ferguson's delta) on the survey as a whole. Brief descriptions are provided in Table 2, as are values for one sample of science students from Thailand. See Ding et al. (2006) for complete descriptions of the statistics. Individual items were evaluated and none were found to be inconsistent with acceptable values.

Table 2: Statistical Tests and Values for Thai students

Test statistic	Possible values	Desired values	Thai language Science (N=188)
Item difficulty index is the fraction of students who answered each item correctly. When the mean of all items is considered, higher values indicate that the survey is easier.	[0, 1]	>0.3 and <0.8	Mean value for survey 0.42
Item discrimination index quantifies how well each item discriminates between high scoring and poor scoring students. When the mean of all items is considered, higher values indicate that the survey has better discriminatory power.	[-1, 1]	0.3	Mean value for survey 0.41
Point biserial coefficient is a correlation between the score on each item and the whole test score for all students. When the mean of all items is considered, higher values indicate that the survey has better internal consistency.	[-1, 1]	0.2	Mean value for survey 0.26
Kuder-Richardson's formula 21 test reliability index measures how consistently students are answering across sections of the survey.	[0, 1]	0.7	0.76
Ferguson's delta indicates how well the survey spreads the scores by considering the distribution of scores.	[0, 1]	0.9	0.96

Method

Participants. The sample was drawn from first year general physics at the Ubon Ratchathani University during the academic year of 2013 and 2014. The sample was selected by purposive sampling method. The two groups was administered a pre-test (the 110 Engineering students in 2013 and 90 Engineering students in 2014.

Procedure. The students did the survey during lecture of their general physics course. The pre-test was done during lectures but prior to commencing the thermal physics contents for the general physics course that taught by physics lecturers from faculty of science at the Ubon Ratchathani University.

Results and discussion

Table 3: Mean Scores for the Engineering Students

Pre-test			
Gender	N	Mean (%)	Std. deviation (%)
Male	85	45.19	16.37
Female	115	38.39	10.48
Total	200	41.28	13.69

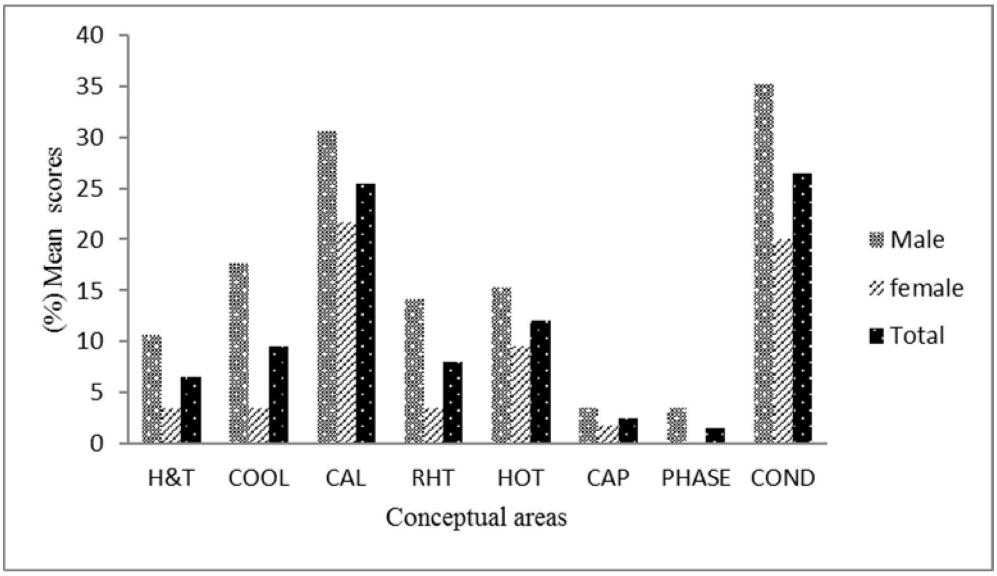

Figure 1: Mean scores in each conceptual area for the different gender.

Understanding of concepts. This study, it was to investigate students' conception of heat and temperature, rate of cooling, calorimetry rate of heat transfer, perception of hotness, specific heat capacity, change of phase and thermal conductivity. From the figure 1, the percentage of most students in COND conceptual area was the highest (26.5%) followed by CAL (25.5%) and HOT (12.0%). There was only 6.5% of students who gave correct responses in H&T, 9.5% in COOL, 8% in RHT, 2.5% in CAP. The percentage of most students in PHASE conceptual area was the lowest (26.5%).

Gender differences. Figure 1 shows the mean score for each conceptual area for the deferent gender. Using a *t*-test, we find that there is a statistically significant difference between females and males in the pre-test mean score (t=3.571, p=0.000, 2-tailed, equal variances assumed) as show in Table 3. We note three points. First, the mean scores are lower than those for male. Second, *specific heat capacity* and *Change of phase* both require proportional reasoning and are problematic. Last, and perhaps surprisingly, *heat and temperature and rate of heat transfer* are also difficult as show in figure 1. These align with areas identified to be conceptually difficult by other researchers such as Harrison, Grayson and Treagust (1999) and Jasien and Oberem (2002).

The results from the survey students have conceptions in different type of understanding. Although, students have been taught in high schools, most students did not give answers correctly in some item. They gave answers that were classified into several categories of conception. The result from this study can be used to indicate that most students are lack of a basic concept on heat and temperature, rate of cooling , rate of heat transfer, perception of hotness, specific heat capacity, and change of phase even though they had been taught already in the secondary level. This is hardly acceptable that even the correct responses to the survey on those conceptual areas as show in the figure 1. The classroom should mainly be the source to provide for the students. The way to provide should not be one way talk because the information given is easily forgotten. Students act only as passive listeners. They are told almost everything. The most appropriate method is two way talking or active learning. Teachers acting as facilitator only encourage students to think for themselves and allow them to participate in the learning process and find out what really happen on their own based on appropriate information provided. This means that no complete information is given beforehand. Therefore, they should be able develop scientific thinking to explain any situation they encounter (Knight. 2004).

Conclusion

The Thai language version of the HTCE survey was found to have consistent reliability, providing meaningful data for surveying students' conception in thermal physics topic. Basic concepts such as *specific heat capacity* and *phase change* were problematic for the class. We found that there is a statistically significant difference between females and males in the pre-test mean score. The result indicated that their understandings still need to be improved. Further, some demonstrations will be used to help students to improve their understandings.

Suggestions

1. Instructors should plan to investigate student conceptual understanding of the material after instruction using the HTCE survey and analyze the normalized gains in all the students' conceptual areas.

2. The overall results from this study show that students should be prompted to improve their understanding of physics concepts by active learning such as the use of ILDs, the use of MBL tools in demonstrations and others.

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