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Surveying introductory physics students' understanding of heat and temperature

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The purpose of this study is to measure introductory students' conceptual understanding of heat and temperature using the Heat and Temperature Conceptual Evaluation survey developed by Thornton and Sokoloff. In 2006 a total of 420 first year Thai students were tested before the standard first year university instruction on thermal physics began. This study compares students' conceptual understandings pre-instruction. The mean pre-test score for Science students, Agriculture students and Engineering students are 34.3, 33.3 and 36.5 percent respectively. Preliminary findings indicate that students from three enrolled degrees have common misconceptions relating to heat and temperature; namely, the rate of heat transfer, specific heat capacity and change of phase. This study could be used as a guide for developing teaching methods on an introductory physics course.

1. INTRODUCTION

The purpose of some physics education research is to study students' understandings or misconceptions in introductory physics using standardized tests. Examples of well known tests include the Force and Motion Conceptual Evaluation test (FMCE) [1], the Electric Circuits Conceptual Evaluation test (ECCE) [2], and the Heat and Temperature Conceptual Evaluation survey (HTCE) [3]. This study focuses on the HTCE survey. Recent research has shown that students have difficulties understanding basic thermal physics. For example, Harrison, Grayson and Treagust [4], Carlton [5], and Yeo and Zadnik [6] all found that students are unable to differentiate clearly between the concepts of heat and temperature. Researchers have subsequently tried to improve conceptual understanding of thermal physics by designing active teaching methods, such as RealTime Physics [7]. Wittmann and Breen [8] have shown that students learn more successfully in such classes than with traditional instruction. The aim of the present project was to use a standard test to measure students' conceptions of thermal physics and compare pre-test results for first year students.

2. METHODOLOGY

2.1 Study Sample

In 2006, 420 first year Thai students were surveyed using the Heat and Temperature Conceptual Evaluation survey in Thai. The students were from general physics courses which are divided by degree enrolled. There are three enrolled degrees which are Science, Agriculture and Engineering degrees. All classes are taught by traditional teaching methods. In all classes, the survey was done *pre-instruction*.

TABLE 1. Categories of conceptual areas.

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

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2.2 The Conceptual Test

The HTCE is a multiple-choice with 28 items, the survey dealing with some basic concepts related to thermal physics. This survey takes about 40 minutes to complete. For this study, the questions of the HTCE survey are divided into eight "conceptual areas" (see table 1). One item requires students to draw a graph (item 24) and has been removed from the analysis because it is difficult to mark objectively.

The HTCE survey covers all topics in thermal physics taught in the high school. Examples of The questions that students have low mean pre-test scores are question 10 and 11.

10. Small coffee cup heaters are placed in cups A and heat is transferred to keep the cups at the temperatures shown. The cups contain the same amount of water. Which answer best describes the rate that heat must be transferred to maintain the temperatures shown?

Cup A will require heat at

A) *about five times the rate of* B

B) *about twice the rate of* B

C) *a slightly faster rate than* B

Both cups will require heat at

D) *the same rate*

Cup B will require heat at

E) *about five times the rate of* A

F) *about twice the rate of* A

G) *a slightly faster rate than* A

H) *None of the above answers is correct*

11. Cup A in the previous question is placed outside where the temperature is 5°C. Compare the rate at which heat must be transferred to keep the water at 45°C outdoors to the rate required to keep the water at 45°C inside the room. (Pick one of the choices A-H below.)

When the cup is *outside*, more heat must be transferred

A) *at about five times the rate as inside*

B) *at about twice the rate as inside*

C) *at a slightly faster rate than inside*

D) *Heat must be transferred at the same rate outside and inside*

When the cup is *inside*, more heat must be transferred

E) *at about five times the rate as outside*

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F) *at about twice the rate as outside*
G) *at a slightly faster rate than outside*
H) *None of the above answers is correct*

The HTCE survey can be downloaded from: http://physics.dickinson.edu/~wp_web/wp_resources/wp_assessment.html#HTCE

2.3 The Thai Translation

The English language version of the HTCE survey was translated into Thai and validated by a panel of five experienced physicists. All questions retained their physics content and distracters targeting specific conceptions. In two of the items the context of the physics was changed; in items 12 and 13, ‘snow outside’ was changed to ‘within a refrigerator’ because snow is unfamiliar to Thai students.

Ten Thai physics postgraduate students took the English language version of the HTCE and a month later took the Thai language version. Responses were compared. 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.

3. RESULTS AND DISCUSSION

Fig. 1 shows students’ mean scores of three enrolled degrees in pre-test for the 8 individual conceptual areas. It can be seen that mean scores of all student enrolled degrees are similar in each conceptual area. The three student groups have lowest mean scores in conceptual area 4 (Rate of heat transfer) that consist of two question (question 10 and 11), highest mean scores in conceptual area 5 (Perception of hotness).

Fig. 2 shows the same data rearranged to display how well the 8 individual “conceptual areas” were understood. In this bar graph, only students who got *all questions for a concept correct* were counted as having understood that concept.

The result indicates that most students have misconceptions. It is only the eighth concept (Thermal conductivity) for which the percentage of all students is higher than other conceptual areas. Most problematic are the rate of heat transfer (conceptual area 4), specific heat capacity (conceptual area 6), and change of phase (conceptual area 7). This study also indicates that students at the different degree enrolled are at the same stages of conceptual areas.

Using *t*-test, there is no statistically significant difference in the pre-test mean scores between students from three enrolled degrees (see Table 2). Students from all enrolled degrees have misconceptions in the same conceptual areas so it is interesting to deeply consider those areas.

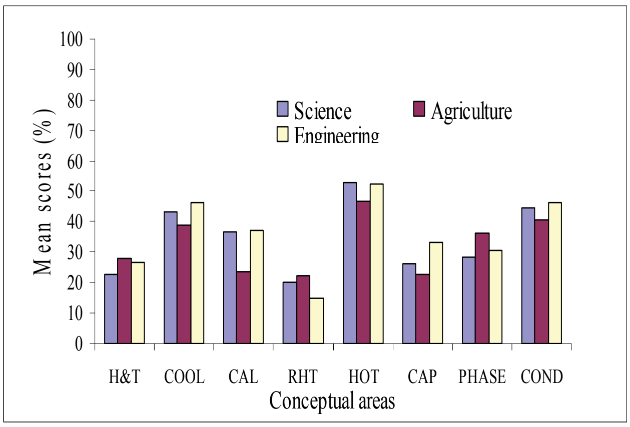

FIGURE 1. Mean scores in each conceptual area for the different student groups.

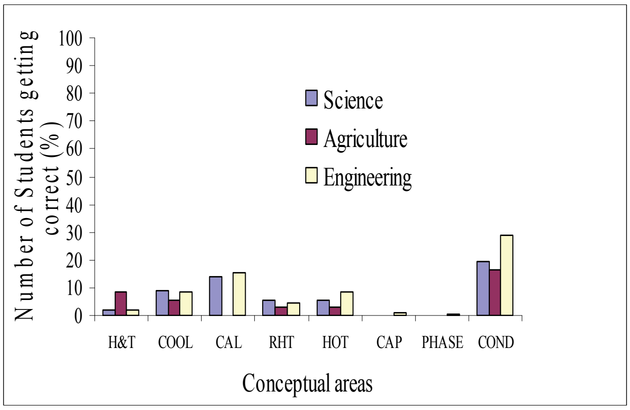

FIGURE 2. Comparison of the percentage of students who provided correct answers for all questions for a particular conceptual area.

TABLE 2. Students’ mean score and standard deviation in pre-test according to their enrolled degrees.

Degree/Class	N	Mean (%)	Std. deviation (%)
Science	57	34.3	9.7
Agriculture	36	33.3	10.9
Engineering	327	36.5	11.7
Total	Female, n=147	37.5	11.9
	Male, n=273	33.0	9.9
Total	420	35.9	11.4

4. CONCLUSIONS

This study indicates that the concepts relating to heat and temperature, the rate of heat transfer, specific heat capacity and change of phase generate significant misconceptions that need to be corrected. This could be done by accompanying the traditional teaching with active teaching/learning methods for the topic of heat and temperature.

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1. R. K. Thorton and D. R. Sokoloff, *Am. J. Phys.* **66** (1997) 338.
2. D. P.Maloney, T. L. O′Kuma, C. J. Hieggelke and A. V. Heuvelen, *Am. J. Phys.* **69** (2001) 12.
3. R. K. Thorton and D. R. Sokoloff. http://physics.dickinson.edu/~wp_web/wp_resources/wp_assessment.html#HTCE [2006, June 15].
4. A. G. Harrison, D. J. Grayson, and D. F. Treagust, *J. Res. Sci. Teach.* **36** (1999) 55.
5. K. Carlton, *Phys. Educ.* **35** (2) (2000) 101.
6. S.Yeo and M. Zadnik, *Phys. Teach.* 39 (2001) 496.
7. D. R. Sokoloff, Real time physics module 2: Heat and Thermodynamics (USA: Wiley Press 2004).
8. M. C. Wittmann and C. V.Breen, Interim report for Realtime and Interactive Lecture Demonstrations Dissemination Project (RTP/ILDs). The Fund for the Improvement of Postsecondary Education (FIPSE) meeting, MD, USA, Nov. 2000.