Surveying Thai and Sydney introductory physics students' understandings of heat and temperature

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***Abstract**: In 2005 a project was undertaken at Mahidol University of Thailand. The aim of the project was to measure introductory students' conceptual understanding of heat and temperature. In 2006 the project has been extended to the University of Sydney with the additional aim of comparing across the Universities. Students' conceptual understanding of heat and temperature is being measured using the Heat and Temperature Conceptual Evaluation survey. A total of 910 Thai and 317 Australian students have been tested after standard first year university instruction on thermal physics. This paper compares Thai and Australian students' conceptual understandings post instruction. Preliminary findings indicate that both Thai and Australian students have significant misconceptions relating to phase change and the rate of heat transfer. Commonalities indicate that the Thai version of the HTCE survey compares well with the English version.*

Introduction

Recent research has shown that students have difficulties understanding thermal physics. For example, Harrison, Grayson and Treagust (1999), Carlton (2000), and Yeo and Zadnik (2001) all found that students are unable to differentiate clearly between the concepts of heat and temperature. Some researchers have subsequently tried to improve conceptual understandings of thermal physics by designing active teaching methods, such as RealTime Physics (Sokoloff 2004). Wittmann and Breen (2000) 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 explore students' conceptions of thermal physics and compare Thai students with Australian students. The emphasis was on studying the response of large lecture classes, rather than attempting to gain detailed insight into individual students' misconceptions.

Method

In 2005, 910 students from three Thai Universities and 317 students from The University of Sydney were surveyed using the Heat and Temperature Conceptual Evaluation survey, developed by Thornton and Sokoloff (HTCE, Assessment Examinations 2004). Table 1 shows the numbers of students from each university and the degree they were enrolled in.

Table 1. Number of students from each degree/class for three Thai universities and The University of Sydney

University	Degree/class	Number (n)
Ubon Rajathanee University (UBU)	Science (SC)	188
	Engineering (EN)	261
Khon Kaen University (KKU)	Science (SC)	165
	Education (ED)	32
Mahidol University (MU)	Science (SC)	264
University of Sydney (USYD)	Regular (Reg.)	200
	Advanced (Adv.)	117

It is worth noting that Mahidol University (MU) is a large metropolitan university in Bangkok, with roughly 12000 students. Khon Kaen University (KKU) is in a large provincial city with 10000 students. Ubon Rajathanee University (UBU) is in a smallish provincial city and has 4400 students. For comparison, the University of Sydney (USYD) is also a large metropolitan university with some 30000 students.

In all cases the survey was administered *post instruction*, within two weeks of the end of lectures. However, Thai students were administered a Thai language version and the Sydney students an English version. The Thai version was translated by the authors of this paper. Both Thai and Sydney students were taught by traditional teaching methods, although there were some differences in the teaching techniques. For example, in-class demonstrations were used in Sydney but no demonstrations in Thailand.

The conceptual test

The HTCE survey is a 28 item, multiple choice survey dealing with some basic concepts related to thermal physics. One item requires students to draw a graph (item 24) and has been removed from the analysis. This test takes about 40 minutes to complete. For this research, the questions on the HTCE survey are divided into eight "conceptions" (see Table 2).

Table 2. Categories of conceptions

Conceptions	Question Numbers
1. Heat and temperature	1, 2, 3, 4
2. Rate of cooling	5, 6, 7
3. Calorimetery	8, 9
4. Rate of heat transfer	10, 11
5. Perception of hotness	12, 13, 14, 15
6. Specific heat capacity	16, 17, 18, 19
7. Change of phase	20, 21, 22, 23, 25
8. Thermal conductivity	26, 27, 28

Results and discussion

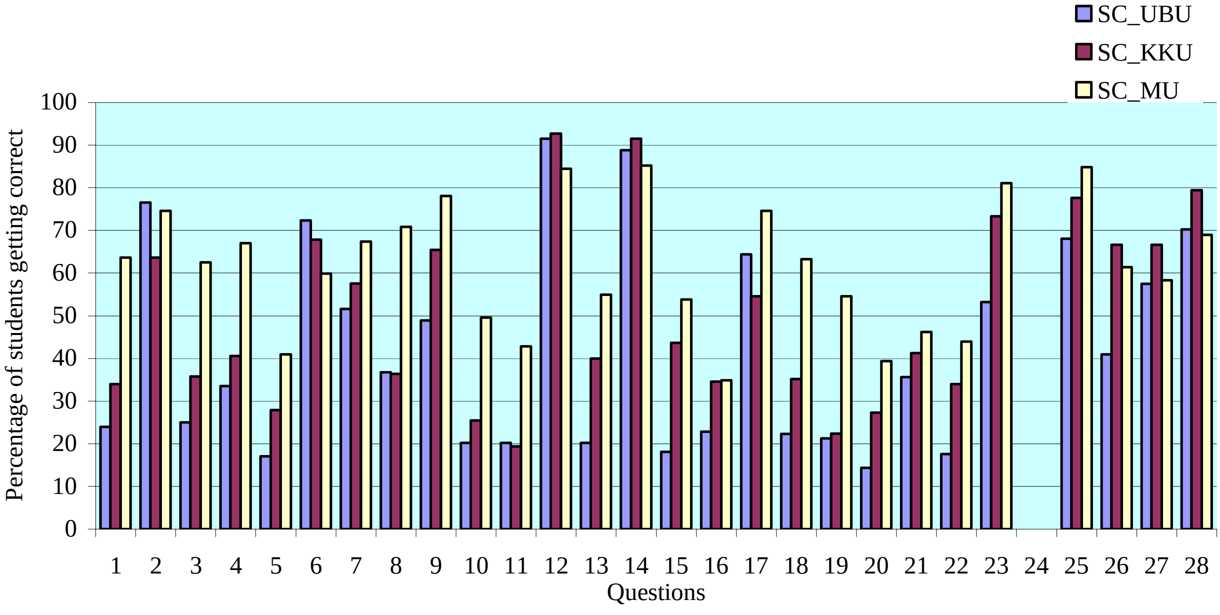

Figure 1. Comparison of percentage of students answering each question correctly from the three Thai universities

Figure 1 shows the percentage of science students answering each question correctly from the three Thai universities. Only students who completed the survey are included (see Table 1).

It can be seen that students from MU provide more correct answers for most questions, followed by KKU and then UBU. There are some questions in which students from UBU do better such as questions 2 and 6. Students from KKU do best on questions 12, 14, 26, 27 and 28. The mean test score of science students from MU is the highest (61.8%), followed by KKU (51.2%) then UBU (41.9%). A chi squared test on the different multiple choice items of all 27 questions separately, shows that students exhibit different understandings at different universities, as evidenced by a statistically significant difference between the distributions of multiple choices items chosen.

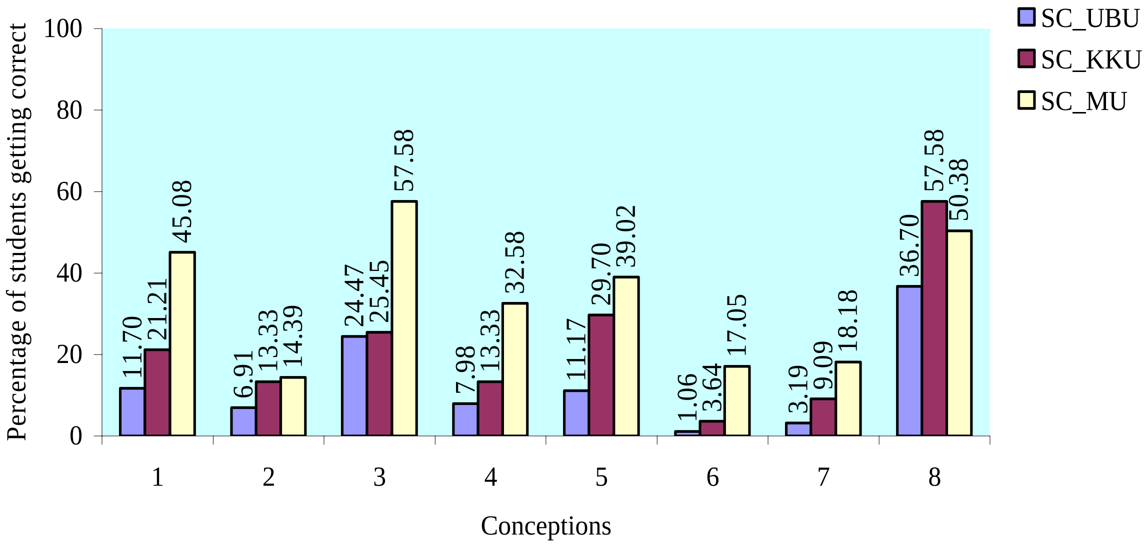

Figure 2. Comparison of conceptions between three Thai universities, numbers show the percentage of students who provided correct answers for all questions for a particular conception.

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

As expected, the earlier pattern is repeated, students from MU understand more concepts, followed by KKU then UBU. It is only the eighth concept (thermal conductivity) for which the percentage of students from KKU is the highest. The result indicates that most science students have misconceptions. Most problematic are the rate of cooling (concept 2), specific heat capacity (concept 6), and change of phase (concept 7). This study also indicates that students at the different universities are at different stages of conceptual development. For a discussion of theories of conceptual development and conceptual change see Chi, Slotta and de Leeuw (1994) and Duit and Treagust (1998).

International comparison

In order to relate Thai and Australian students, we have chosen science students from MU and students in the *Regular stream* of first year physics from the University of Sydney (USYD). At USYD, students doing mainstream physics are divided into an Advanced stream (students who have done senior high school physics and are high achieving students) and a Regular stream (students who have done well in senior high school physics).

The reason for comparing science students at MU with the Regular stream from USYD is that there are similar numbers of students in the two groups (n = 200 for Regular students at USYD and

264 for science students at MU), and they have similar background knowledge (mean score on the HTCE survey for USYD is 68.9% and for MU is 61.7%).

Figure 3 shows the percentage of students answering each question correctly from MU and USYD. It is clear that students from USYD provide more correct answers than MU for most questions, though there are some questions in which students from MU do better (questions 21, 23 and 25).

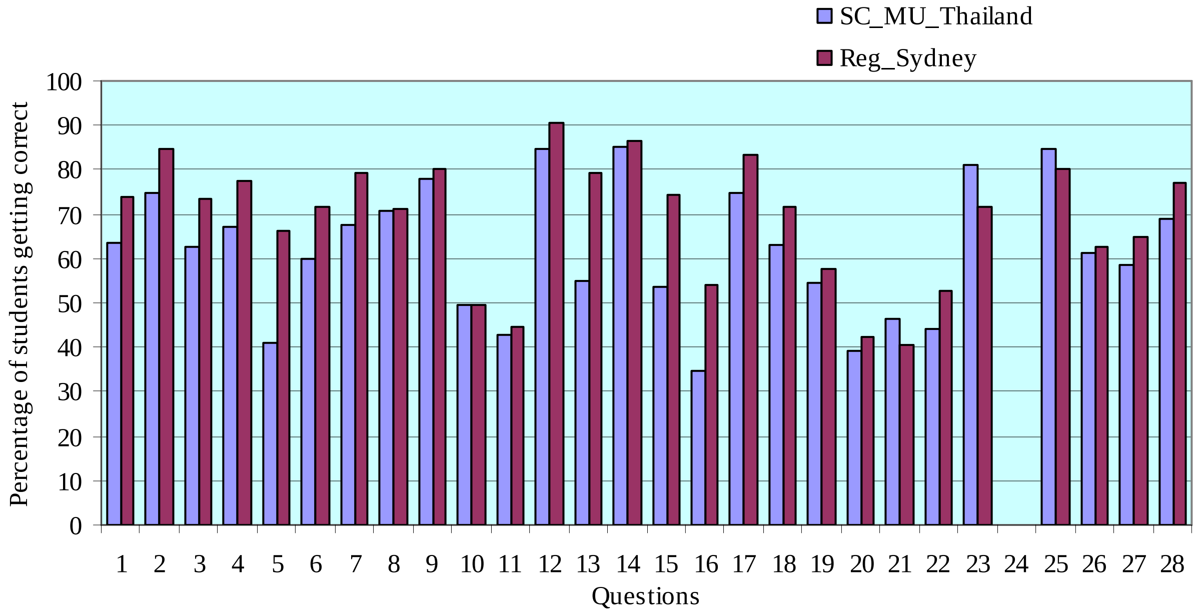

Figure 3. Percentage of Science students at Mahidol University and Regular students at University of Sydney answering each question correctly

From the results, most science students from MU and USYD have difficulty answering questions 10, 11, 20, 21 and 22. Question 10 has the smallest difference in the percentages of students giving the correct answer. Again a chi squared test was performed on the multiple choice items of all questions separately. This showed that, students in the two groups exhibited different understandings for all questions except 9 and 10.

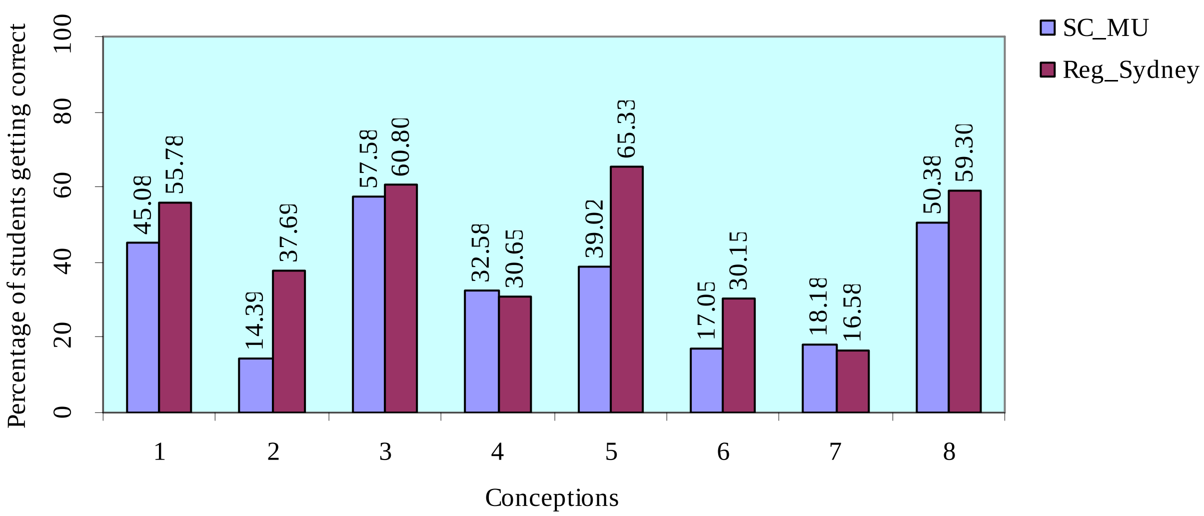

Figure 4. Comparison of conceptions between Science students at Mahidol University and Regular students at University of Sydney

Figure 4 shows the percentage of students who have understood each of the eight conceptions. The results indicate that most science students have difficulty understanding rate of cooling (concept 2), specific heat capacity (concept 6), and change of phase (concept 7).

Conclusion

This study indicates that both Thai and Australian students have significant misconceptions relating to phase change and rate of heat transfer. Most students have good understanding of boiling point.

In order to compare students from Thailand with those from Australia, we had to find similar groups of students. Across the institutions in Thailand there were significant differences between the five cohorts. However, we found that Science students from MU and Regular students from USYD were comparable. The results from these two institutions were sufficiently similar to confirm that the measuring instrument (the HTCE survey) is robust for comparing students' understandings of thermal physics, which further implies that the initial English-Thai translation was valid.

A possible next step in this research is to improve teaching method to address student misconceptions. It would then be useful to reapply the Heat and Temperature Conceptual Evaluation survey to see if the situation improves.

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