THE EFFECTS OF PHYSICS BREADTH COURSES ON STUDENT ATTITUDES ABOUT SCIENCE

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At the University of Toronto (U of T), students must specialize in one or more disciplines and take a small number of courses outside their areas of specialization. So-called "breadth courses" serve to expose students to areas of knowledge and critical methods outside their primary area of study. Physics breadth courses give students pursuing non-science degrees insight into how physicists think and approach problems. While instructors aim to increase our students' knowledge of physics facts and concepts, a more fundamental goal is to cultivate a long-lasting appreciation of evidence-based methods of inquiry. Yet our assessment methods rarely probe student attitudes; these methods tend to test accumulation of knowledge and mathematical abilities.

SURVEY METHODS

The CLASS survey [1] asks students to respond to 42 statements on a five point scale from A: 'strongly disagree' to E: 'strongly agree'. When physicists answer, 36 of the statements elicit strong consensuses. Student responses to these 36 statements can be scored to quantify how expert-like or novice-like their attitudes are. Between fall 2003 and fall 2005, the creators of CLASS administered the survey to over 7000 students in 60 different physics courses. Based on the results, they developed eight empirically determined, non-mutually-exclusive categories: "Personal Interest" (PI), "Real-World Connections" (RWC), "Problem Solving General" (PWG), "Problem Solving Confidence" (PSC), "Problem Solving Sophistication" (PSS), "Sense Making and/or Effort" (SME), "Conceptual Connections" (CC) and "Applied Conceptual Understanding" (ACU).

SUMMARY

We administered the Colorado Learning Attitudes About Science Survey (CLASS) at the beginning and end of four physics breadth courses, and found a slight improvement in CLASS scores when interactive teaching methods were used, as well as a difference in CLASS scores and gain for students with different high school physics backgrounds.

We attempted to measure student attitudes using CLASS in two different physics breadth courses at U of T: (1) PHY100 "The Magic of Physics", in which we surveyed 234 students over the spring and summer of 2013, and (2) PHY205 "Physics of Everyday Life" in which we surveyed 461 over the spring and summer of 2013. PHY100 explored a range of introductory physics topics, with traditional lectures and tutorials that involved minimal formal student participation. PHY205 was taught by one of us (JJBH), and every class clicker remotes were used in lectures to promote in-class discussions. Every week students worked in teams of 3 in tutorials to make measurements and observations using simple laboratory equipment.

We administered CLASS in the first and last weeks of each semester to obtain the pre and post-course scores. We asked students about their backgrounds, and offered students no marks incentives for participating. Of 695 enrolled students, 414 wrote the pre-course survey, 470 wrote the post-course survey, and 330 wrote both. The average final mark of students who wrote both surveys was 77%, while the average final mark of the 143 students who wrote neither survey was 62%. Since surveys were done on paper during tutorials, lower marks may be attributable to students who tend to skip tutorials.

Although students responded to the CLASS statements on a five point scale, we analyzed the survey data on a two point scale, in line with other researchers using CLASS [2–4]. For each of the 18 statements with which experts tend to agree, we counted 'agree' and 'strongly agree' as favourable responses. For each of the 18 statements with which experts tend to disagree, we counted 'disagree' and 'strongly disagree' as favourable. We did not score the 5 statements for which CLASS researchers found no strong expert agreement, nor a control statement used to identify students who may be choosing random answers.

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TABLE 1

COMPARISON OF PRE- AND POST- CLASS RESULTS FOR THE TWO BREADTH COURSES OF THIS STUDY. AVERAGE PERCENTAGE OF FAVOURABLE RESPONSES IS SHOWN, WITH STANDARD ERROR OF THE MEAN IN PARENTHESES. SHIFTS THAT ARE STATISTICALLY SIGNIFICANT AT THE $p < 0.05$ LEVEL ARE SHOWN IN BOLD.

	PHY100 ($N = 93$) "Magic of Physics"			PHY205 ($N = 237$) "Physics of Everyday Life"		
CLASS category	**Pre**	**Post**	**Shift**	**Pre**	**Post**	**Shift**
Overall	57.4 (1.6)	56.5 (1.9)	−0.9	58.3 (1.0)	60.1 (1.0)	+1.7
Personal Interest	60.8 (2.7)	64.2 (3.4)	+3.4	62.4 (1.7)	65.0 (1.7)	+2.7
Real World Connections	73.7 (2.7)	72.6 (3.1)	−1.1	69.2 (1.8)	72.7 (1.7)	+3.5
Problem Solving General	61.2 (2.7)	61.7 (2.7)	+0.5	64.7 (1.6)	67.2 (1.6)	+2.5
Problem Solving Confidence	59.4 (3.4)	59.4 (3.2)	0.0	60.9 (2.0)	66.8 (2.0)	**+5.9**
Problem Solving Sophistication	45.7 (3.0)	45.5 (3.1)	−0.2	47.0 (1.8)	50.9 (1.8)	**+3.9**
Sense Making and/or Effort	68.8 (2.2)	64.2 (2.5)	−4.6	71.1 (1.4)	71.6 (1.4)	+0.5
Conceptual Connections	54.3 (2.6)	51.4 (2.9)	−2.9	55.9 (1.7)	56.9 (1.9)	+1.0
Applied Concept Understanding	40.9 (2.2)	39.2 (2.6)	−1.7	42.0 (1.4)	43.6 (1.7)	+1.6

RESULTS

Table 1 shows the average percentage of favourable responses, both overall and for the eight specific categories, for all 330 students who wrote both the pre- and post-course surveys.

Lack of Significant Decrease in Favourable Attitudes

Some studies have shown a significant decline in the percentage of favourable responses after taking introductory physics courses [1–3]. In our study, PHY100, with its traditional lectures and tutorials, resulted in a slight downward shift in overall CLASS score of $-0.9 \pm 1.6\%$ over one semester. PHY205, which incorporated a more interactive teaching style in lectures, and a more hands-on approach in tutorials, produced a slight upward shift in overall CLASS scores of $+1.7 \pm 0.9\%$.

In PHY205, for the Problem Solving Confidence (PSC) category, we saw a statistically significant increase in percentage favourable responses from $60.9 \pm 2.0\%$ up to $66.8 \pm 2.0\%$, which is a $+2.8\sigma$ gain over the semester. The paired t test shows the probability of the pre- and post- scores being the same for the PSC category is 0.6%. Multiplied by the number of categories we considered (8), the probability is still less than 5%.

CLASS Scores and Student Backgrounds

Physics breadth courses are designed for non-science students with little prior physics experience. However, 44% of the students had taken grade 12 physics in high school, and 37% identified their area of study to be either physical sciences, life sciences or computer science. We compared CLASS scores and shifts for the arts and science majors, and the students with and without grade 12 physics.

We found no statistically significant differences in scores or shifts between the arts and science students in our courses. However, prior physics coursework correlated reliably with CLASS scores. The results are presented in Table 2. At the beginning of the course, the 203 students who had not taken grade 12 physics had an average overall CLASS score of $54.8 \pm 1.0\%$, while the 152 students who had taken grade 12 physics got $61.2 \pm 1.2\%$ - a difference of over 5σ. It could be expected that students who took physics in high school also took other science courses, and were therefore exposed to scientific reasoning before even coming to U of T. A similar positive correlation between high school physics and pre-course CLASS scores was found at our neighbour, Ryerson University [4].

As seen in Table 2, the shifts in CLASS scores over one semester for students who had taken grade 12 physics were insignificant. However, the overall shift for students without grade 12 physics was $+2.2 \pm 1.1\%$, and there were three categories, PI, PSC and PSS, for which we measured a statistically significant upward shift. The paired t test probabilities for these three categories having no shift were 0.8%, 0.9% and 0.5%, respectively. This suggests that students with less of a science background have more to gain from breadth courses.

TABLE 2

Pre-course CLASS average scores for students with different high school backgrounds taking either of the breadth courses in this study. Average percentage of favourable responses is shown, with standard error of the mean in parentheses. The shift from the beginning of the course to the end of the course is also shown. Shifts that are statistically significant at the $p < 0.05$ level are shown in bold.

	No Grade 12 Physics ($N = 203$)		Grade 12 Physics ($N = 152$)	
CLASS category	**Pre-course**	**Post Minus Pre**	**Pre-course**	**Post Minus Pre**
Overall	54.8 (1.0)	+2.2 (1.1)	61.2 (1.2)	−0.3 (1.4)
Personal Interest	56.3 (1.8)	**+6.1 (2.2)**	65.7 (2.0)	−0.5 (2.4)
Real World Connections	67.7 (2.0)	+4.5 (2.4)	71.4 (2.1)	−0.8 (2.5)
Problem Solving General	57.6 (1.7)	**+4.4 (1.9)**	70.6 (1.9)	−1.3 (2.2)
Problem Solving Confidence	54.7 (2.1)	**+6.7 (2.5)**	67.3 (2.5)	+1.3 (2.9)
Problem Solving Sophistication	38.3 (1.8)	**+6.5 (2.3)**	56.1 (2.1)	−0.6 (2.4)
Sense Making and/or Effort	68.0 (1.5)	−1.7 (1.8)	71.0 (1.8)	−0.5 (2.0)
Conceptual Connections	50.1 (1.8)	+2.7 (2.1)	61.2 (2.0)	−2.2 (2.5)
Applied Conceptual Understanding	37.2 (1.5)	+2.8 (1.9)	47.3 (1.8)	+2.2 (2.1)

CONCLUSIONS

This was an exploratory study of CLASS results for physics courses aimed at non-science students. We did not find negative shifts over a single-semester, as reported in other studies [1–3]. We found a slight positive shift for our course that involved interactive teaching techniques and hands-on tutorial activities. We also found a positive shift for students who had not taken grade 12 physics in high school. Students who had taken grade 12 physics started out with better attitudes, but their attitudes did not shift over the semester.

Future work could focus on which classroom activities have a positive effect on student attitudes, and what assessment methods would better measure attitudes about science.

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