A longitudinal study of the development of attitudes and beliefs towards physics

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Abstract. Student success in a physics degree has been shown to depend on more than just performance in course assessment: important additional factors include student attitudes and beliefs about their subject. We have used an instrument (CLASS) that measures how student epistemologies evolve over the course of their undergraduate degree. Our previous work has sampled a cross-section of students at all levels across the physics undergraduate programme at Edinburgh in a single academic year, and found that student attitudes and beliefs remain essentially static. Here, we present fully longitudinal data collected over the past three years, where we track the evolution of the attitudes and beliefs of one group of students. We find broadly similar results: attitudes and beliefs remain surprisingly consistent over time. This suggests that a 'cross-sectional' or 'pseudo-longitudinal' study (collecting snapshot data in one year) is a valid methodology, rather than necessarily having to wait several years to accumulate truly longitudinal data.

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INTRODUCTION

The investigation of student attitudes towards study, and the effect that these attitudes may have on a student's ability to perform, has been of marked interest to science education researchers for some time. Through the emergence of survey instruments specifically designed to measure attitudes and beliefs and how they change over time [1, 2, 3], researchers and instructors are becoming increasingly able to assign quantitative values to an area perhaps often thought of as far more qualitative and, through this, examine the effect that teaching can have on student attitudes and learning.

The Colorado Learning Attitudes about Science Survey (CLASS) [4] has become one of the most widely used instruments to examine student attitudes towards study in the discipline of physics. The most common application of the survey instrument has been to look at the changes in student attitudes after one period of first year instruction (either one semester or one year) with virtually all studies (regardless of university type or geographic location) showing that students decline in expert-like thinking [4, 5, 6], unless taught on a course which specifically targets student epistemologies [7, 8]. There are few studies that consider how student attitudes change after the initial period of instruction, although those that have been carried out suggest student attitudes are largely constant over the course of a degree [9, 10]. The timescales involved in assessing student attitudes over the entire duration of a degree program mean that most studies that have emerged use a cross-sectional method, where students in various classes are surveyed in the same academic year and inter-year comparisons are drawn. In this paper, the results of the first three years of a fully longitudinal study are presented, with the attitudes of the same group of students being tracked as they progress through a physics degree, from the first week of teaching in freshman year to the last week in junior year.

METHODOLOGY

In the following sections we will outline the educational context within which this study was carried out, briefly describe the survey instrument and give details of how the study was implemented.

The CLASS survey

The CLASS survey aims to probe student attitudes and beliefs towards physics by comparing student responses to 42 attitudinal questions to the answers of expert physicists, thus giving a percentage of 'expert-like thinking'. Overall percentage scores are calculated for both 'favorable' expert-like thinking, the percentage to which the answers of the class agree with an expert opinion, and 'unfavorable' expert-like thinking, the extent to which they are at odds with the expert opinion. The responses can be further subdivided into eight categories of types of thinking, each of which can also be scored to give a percentage of expert agreement. The survey instrument has been used extensively both to examine changes in attitudes in their own right and as a measure of the success of course reforms. For further details of the survey design and validation, interested readers should refer to papers by the survey authors [4].

Educational context

This study has been carried out at the University of Edinburgh in Scotland, UK. The University of Edinburgh is a traditional research based university, which selects potential students from those achieving the highest grades in high-school.

Physics degrees in Scotland are usually awarded after four years of study, leading to a Bachelor of Science degree, or in some cases can consist of five years of study after which students will be awarded a Master in Physics degree. The first year of the degree program is intended to give incoming students a broad coverage of a variety of subjects, with students typically studying one third of their curriculum in physics, one third mathematics and one third chosen by the student from another subject area. As this system is used in most of the first year degree courses across the university, many of those in the first year physics class will be from different degree programs, having chosen to take first year physics as their elective option. No separate physics class is offered for non-majors and all those choosing to take the first year physics class must be as qualified to do so as the majors taking the course. A typical first year class comprises approximately 200-300 students, of which around one half will be physics majors; it is very unusual for any non-majors to take any higher level courses after the first year, and impossible for students to do so from third year upwards. The first year class is taught in a reformed workshop-based style; as students progress through the degree program the higher year courses are taught in an increasingly traditional style. Students are offered little choice in the areas of physics studied until the beginning of the fourth year of the degree program, after which they will largely have free choice from an extensive list of courses. The courses of the program do not place explicit emphasis on the development of student epistemologies.

Implementation of the study

This study commenced in September 2008, on the first day of undergraduate teaching of the 2008-09 academic year. The same cohort of students have been asked to complete the CLASS survey four times: pre and post first year instruction, post second year instruction and, finally, at the end of third year instruction. We have previously reported on our findings pre and post first year instruction [6] and, for brevity, the post instruction results will not be included in this paper. As only matched student responses are of interest in this particular study, some survey responses at each point of sampling have been disregarded (since the particular student failed to complete a corresponding survey at another point in time). Response rates can be seen in Table 1.

TABLE 1. Raw numbers of student surveys collected at each stage of the study, the final numbers used throughout the study and the percentage of surveys retained for students who completed all three surveys.

	Collected	Retained	% Retained
1st Year	265	35	13%
2nd Year	105	35	33%
3rd Year	58	35	60%

The average results for each cohort do not differ significantly by only using the fully matched responses as compared to the complete, non-matched data set. In total, 35 students have completed the initial pre-instruction survey as well as the post second and third year surveys while also passing all relevant checks for the quality of the data.

In all cases the survey was completed in paper format in a set-aside segment of class time. The students were asked to complete the survey without talking to other class members, and while the survey could not be completed anonymously (due to the nature of the study), students were asked only to provide their student ID number and were reassured that the individual survey responses would not be shared with members of the University teaching staff (two of whom are authors on this paper). No course credit or other incentives were offered to the students to complete the survey.

RESULTS

The results obtained in this study can be subdivided into three separate areas of interest: the overall percentages of expert-like thinking for each cohort, the scores in each CLASS category per year and, finally, use of the longitudinal results to validate a cross-sectional method of data collection.

Longitudinal CLASS scores

Figure 1 shows the overall percentage scores at each of the three sample points, with favorable scores plotted against the left hand axis and unfavorable scores on the right hand axis. The figure shows that the overall scores are remarkably constant with no statistically significant differences in any of the transitions shown. Looking first at the favorable data, the first year data (collected prior to any university teaching) records a student average of 70(2)%, which remains constant in second year and drops slightly to 68(3)% by the end of third year. However, an ANOVA test for repeated measurements carried out on all the data shows that there is no statistically significant difference between the years (p=0.54).

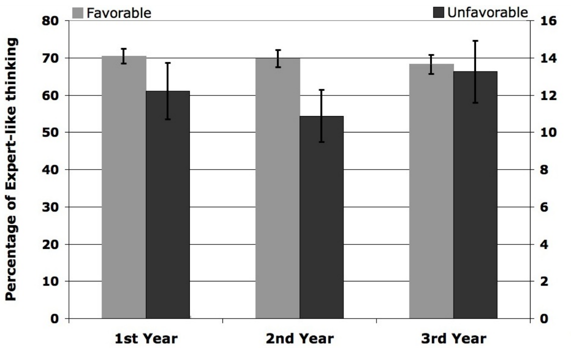

FIGURE 1. Percentage favorable (left axis) and unfavorable (right axis) CLASS scores over three consecutive years for the same group of students (N=35). The error bars in each case represent the standard error on the mean.

Looking now at the unfavorable scores – the percentage to which the answers given are at odds with the expert opinion – again we see no significant changes. The score recorded at the start of the first year of 12(2)% decreases to 11(1)% by the end of second year and is then seen to increase at the end of third year to 13(2)%. Again, using an ANOVA test we find no statistically significant difference between the years (p=0.18).

These results are comparable to those seen in previous cross-sectional studies [9, 11], both in terms of the magnitude of the overall CLASS scores and in the distinct lack of variation in the scores.

Category differences

Further investigation into the expert-like thinking of the students was carried out by splitting the results for each year group into the 8 scored categories of the CLASS survey. For illustrative purposes, percentage shifts for favorable scores in each category are displayed in Figure 2; in this case the changes have been calculated by looking at the differences between the percentage scores in the first year and third year.

Statistical tests (ANOVA) investigating the differences in category score between all years indicate that, in addition to the constancy of the overall CLASS scores, 10 of the 16 possible category measures (8 categories, which can each be scored in both favorable and unfavorable percentages) remain constant between first and third year. For the favorable data, significant shifts are seen in only three categories: firstly in *'General*

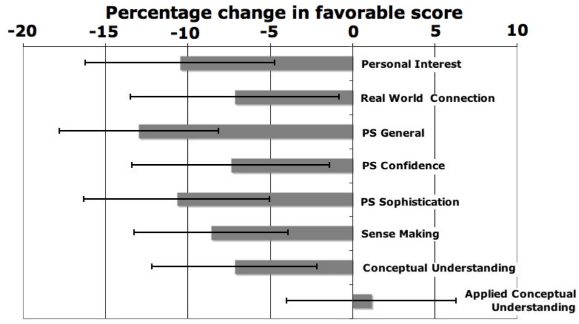

FIGURE 2. Percentage changes in CLASS category favorable scores between 1st and 3rd year.

Problem Solving', where students have declined from 81(3)% expert-like thinking to 68(4)% (p=0.0033); also in *'Personal Interest'*, where students have changed from 76(4)% to 66(4)% (p=0.04); and, finally, in *'Problem Solving Sophistication'*, where students have decreased from 69(4)% to 59(4)% (p=0.015).

In the case of the unfavorable data (not shown), again, three differences are statistically significant: these are in the *'Personal Interest'* category, with students changing from 7(2)% to 15(3)% (p=0.00013); the *'Real World Connection'* category, with a change from 7(2)% to 14(3)% (p=0.025); and lastly in the *'General Problem Solving Category'*, where students have increased in unfavorable expert-like thinking from 7(2)% to 10(2)% (p=0.021) .

A previous study [10] which incorporates the CLASS scores of freshmen and seniors at MIT also finds variation on a category basis despite static overall scores. Significant shifts are seen in three categories: increases in favorable scores for *'Real World Connection'* and in unfavorable scores in the *'Sense Making'* category (neither of which we see) and in the *'Personal Interest'* category, which we also find, with a comparable magnitude of shift.

Validation of cross-sectional studies

We have previously reported [11] on work carried out in a cross-sectional study where all data was collected in one academic year and inter-year comparisons were drawn. The data acquired in the present study appears to support the validity of this method as all the overall score data collected is in agreement with the data obtained in the cross-sectional study. Comparisons between the two sets of data are shown in Figure 3.

As opposed to Figure 1, where the focus is on the changes in student performance between years, in Figure 3 the reader is encouraged to look at bars of the same

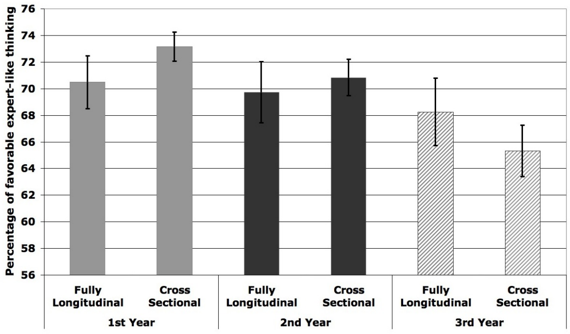

FIGURE 3. Percentage scores of favorable expert-like thinking collected from both a fully longitudinal study and through a cross-sectional study. First year data: N=35 (Fully Longitudinal) and N=127 (Cross-sectional). Second year data: N=35 (Fully Longitudinal) and N=105 (Cross-sectional). Third year data: N=35 (Fully Longitudinal) and N=61 (Cross-sectional).

shading, which compare the data collected through a fully longitudinal method to that obtained in a cross-sectional study for three years of data collection: no significant variations are seen.

Tables 2 and 3 contain the percentage scores (favorable and unfavorable, respectively) for each year group, as collected through both methods, and includes the p values found when comparing the data sets with t-tests. In all cases there are no significant differences between the data collected through either method.

CONCLUSIONS

Although one additional year will be required to collect all the data needed to fully investigate the changes in student attitudes over an entire undergraduate physics degree, initial indications suggest that our students' overall attitudes towards study remain largely static. This is despite the fact that students are being taught using a variety of teaching styles and face increased content knowledge requirements and more complex subject matter.

Furthermore, in addition to the constant nature of the overall scores, no statistically significant changes are seen in 10 out of the 16 CLASS categories. However, two of the categories show significant deterioration in both the favorable and unfavorable categories: *'Personal Interest'* and *'General Problem Solving'*.

Comparison of data collected through a fully longitudinal study to that collected in a cross-sectional study shows no significant differences, suggesting that a cross-sectional method is valid for longitudinal studies using the CLASS instrument; replication studies would help to further establish the validity of such cross-sectional approaches.

Further work is needed to investigate how the attitudes of students will be affected by increased subject choice and freedom in their final year of study, as well as to determine if there is a link between student attitudes and performance in degree examinations.

TABLE 2. Favorable scores collected through fully longitudinal and cross-sectional methods. The abbreviation 'Long.' refers to data collected in the fully longitudinal study and 'C.S.' refers to data collected in a cross-sectional study. The numbers in brackets represent the standard error on the mean.

Year	Long. (%)	C.S. (%)	p value
1st Year	70(2)	73(1)	0.24
2nd Year	70(2)	71(1)	0.68
3rd Year	68(3)	65(2)	0.36

TABLE 3. As in Table 2, but for unfavorable scores.

Year	Long. (%)	C.S. (%)	p value
1st Year	12(2)	11(1)	0.54
2nd Year	11(1)	13(1)	0.26
3rd Year	13(2)	17(2)	0.13

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