The Changes in Attitudes and Beliefs of First Year Physics Undergraduates: A Study Using the CLASS Survey

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Abstract

Personal attitudes and beliefs towards learning can influence the way students approach and study a subject; as a result, evaluation of attitudes and how these change over time is becoming increasingly common. We have carried out a study looking at the changes in attitudes of first year physics students over two years at the University of Edinburgh. The Colorado Learning Attitudes About Science Survey (CLASS) was used to obtain a measure of expert-like thinking for students both pre- and post- first year teaching. The results have been subdivided to look at the differences between physics 'majors' and 'non-majors' as well as the differences in attitudes of female and male students. It was found, in line with previous studies, that students' levels of expert-like thinking decline after initial instruction. When the data was subdivided to look in more detail at specific sections of the undergraduate class it was seen that the decrease in expert-like thinking is much more marked in non-majors - those students not intending to take physics as a degree - and also greater in female students than their male peers.

Introduction

Recently in science education, there has been increased focus on the attitudes students have towards their subject and how these attitudes can affect performance in their chosen degree program (Ogilvie, 2009). These attitudes can be formed from a young age, with aspects such as peer pressure and gender or racial stereotypes playing a large part (Linn & Songer, 1991; Wilson, 2000). The early formation of negative attitudes towards a high school subject, regardless of the origins of this negativity, will generally mean that the student will not choose to study the subject further through a higher education course (Malcom, 2010); however in some cases students will embark on a degree program with attitudes which, although not negative towards the subject, show a naivety which can impede learning (Paulsen & Feldman, 2005).

In order to establish a quantitative measure of attitudes towards science study, an area that perhaps is traditionally thought of as being far more qualitative, a variety of survey instruments have been established to assess the attitudes and beliefs of physics students. These include (although this is not an exhaustive list) the Views of Nature of Science questionnaire (VNOS) (Lederman, Abd-El-Khalick, Bell, & Schwartz, 1998), the Views About Science Survey (VASS) (Halloun & Hestenes, 1998), the Maryland Physics Expectations Survey (MPEX) (Redish, Steinberg & Saul, 1998) and the Colorado Learning Attitudes about Science Survey (CLASS) (Adams, Perkins, & Podolefsky, 2006). Studies undertaken with these instruments have allowed better understanding of the attitudes of science students, the evolution of these attitudes over time and the differences in attitudes between physics students and physics academics and practitioners.

One of the most widely used of these instruments is the Colorado Learning Attitudes about Science Survey (CLASS) (Adams et al., 2006) which has evolved from previous attitudinal surveys as an instrument that allows the calculation of a percentage of expert-like thinking for students by comparing their responses with expert opinions. Results obtained from using the instrument with thousands of students across North America have shown that students often possess a very different set of attitudes and beliefs about their subject to that of physics professionals, with students able to differentiate between how they would answer specific questions, and how they think a physics expert would reply (Gray, Adams, Wieman & Perkins, 2008). Studies have also shown that on entering tertiary education students' levels of expert-like thinking will generally decline and become less expert after one semester of higher education (Adams et al., 2006) unless the curriculum design explicitly addresses these concerns (Brewe, Kramer & O'Brien, 2009; Redish & Hammer, 2009). As in this paper, the survey is traditionally used to look at the changes in attitude of specific students in a class over a year, or even semester of instruction, although there are now a few emerging examples of longer term studies looking at the changes in student attitudes over the course of an undergraduate degree (Bates, Galloway, Loptson, & Slaughter, 2011; Gire, Jones & Price, 2009; Barrantes, Pawl & Pritchard, 2009).

Until very recently the survey has been used almost exclusively in North America. It is now, however, beginning to be used more widely in physics departments across the world (Alhadlaq, Alshaya, Alabdulkareem, Perkins, Adams, & Wieman, 2009; Domert, Airey, Linder, & Lippmann Kung, 2007). To the best of the authors' knowledge this is the first time the instrument has been deployed in the United Kingdom, and will hopefully allow better understanding of the attitudes of physics students in Higher Education programs outside of North America. In this paper we draw comparisons between students studying at a Scottish university, comparing them with those at North American institutions as well as discussing the data in its own right. The overall attitudinal changes of the first year physics class are discussed, after which the data will be dissected further to look more closely at different populations of the class. Specifically we look at students intending to study for a physics degree versus those taking physics to complement another degree choice and we will contrast the attitudes and beliefs of male and female students in the cohort.

Methodology

About the Physics Cohort

In order to set the context of the study, it is necessary to understand the educational background of the students involved. There are two aspects to consider: the nature of the high school systems the undergraduate students have been drawn from and the structure of the undergraduate physics degree at the University of Edinburgh.

In terms of pre-university schooling, the students in the first year physics class are made up of approximately 45% Scottish students and 45% from the rest of the UK, the remaining 10% are EU/International Students. The Scottish educational system differs to that of the rest of the UK meaning that students can enter the degree program with very different levels of preparation.

The Scottish school system involves students studying typically five subjects after the age of 16: the qualifications gained as a result are known as ‘Highers’. These qualifications are considered sufficient to go on to tertiary education; however many students choose to stay in school to complete further study in more depth in (usually) three of these five subjects, pursuing qualifications known as ‘Advanced Highers’. Scottish students can enter university after Highers only or after Highers and Advanced Highers meaning that there is already variation in the amount of prior study the Scottish students may have.

The rest of the UK has qualifications known as Advanced Levels (A-Levels) and Advanced Subsidiary Levels (AS Levels). Four or five AS levels will be studied as the initial education post 16 years of age, after which students will typically choose three of the five subjects to continue to A-Level. Students must have completed A-Levels in order to study at university.

Due to the potential different school exit points for students entering Scottish universities, the Bachelors degree is normally four years long, as opposed to three years at other UK institutions, with the first year offering a broad selection of subjects for students. At the University of Edinburgh, the first year of study for a physics degree typically comprises one third physics, one third mathematics and the final third free choice. This broad-based system is typical of all first year courses in the university, meaning that many students taking other degrees will elect to take first year physics as their additional courses. For the majority of students reading degrees other than physics, taking these courses is an elective option thus leading to students taking the first year physics class from as wide a range of degree disciplines as engineering to Russian studies. In this paper the two types of first year physics students will be referred to as physics ‘majors’ for those studying on a physics degree program and ‘non-majors’ for those taking physics as an outside optional subject. It is important to draw a distinction between the terminologies as used here and its use in North America. Unlike many physics programs in North America, the non-majors taking the course at the University of Edinburgh must have the same entry requirements as their physicist peers i.e. they must have passed either A-Level or Higher Physics to the same grade as the university requires for physics degree program admissions. They are therefore suitably qualified to undertake a physics degree course but have elected to study a different degree program. Another key feature of the non-majors is that they have (in most cases) freely chosen to take physics, as only a very small minority of degree programs (other than those in physics) dictate first year physics as a compulsory course.

The first year physics course consists of two distinct semesters. The first semester is a mechanics based course with interactive lectures making extensive use of electronic voting systems and peer discussion, supplemented with workshops in the place of traditional tutorials (Bates, 2005). The second semester contains an overview of many physics topics that will be studied in more depth at a later point in the degree, such as thermodynamics, quantum mechanics, nuclear physics and particle physics. During the second semester, students also complete introductory laboratory experiments as part of the assessment. The course is considered successful with the first Semester course consistently achieving normalised learning gains of approximately 0.5 (averaged over five years) on the Force Concept Inventory (Hake, 1998; Hestenes, Wells & Swackhamer, 1992) and positive staff and student feedback. The majority of the students taking the courses as elective options take both courses.

Implementation of the study

The CLASS survey comprises 42 items, which investigate how students think about physics by looking at student responses to statements, such as *"A significant problem in learning physics is being able to memorise all the information I need to know"*, *"I cannot learn physics if the teacher doesn't explain things well in class"* and *"I do not spend more than five minutes stuck on a physics problem before giving up or seeking help from someone else"*. All statements are rated from strongly disagree to strongly agree on a 5 point Likert scale.

The survey has been extensively tested and validated, with full details found in publications by the survey designers (Adams et al., 2006; Gray et al., 2008). The student responses are condensed down to disagree, neutral and agree for each statement. These are then compared with the previously collected 'expert' responses to look at the level of agreement; for example in the first statement above the expert opinion would be to disagree with the statement. The term expert in this case is used to refer to practicing physicists working in academic institutions. The answers were collected by the survey designers and from these an 'expert' opinion was determined for the statements.

By aggregating the results for all statements and all students who responded to the survey, the instrument allows a percentage of expert-like thinking to be calculated, for a whole class. It will also, conversely, give a percentage of unfavourable responses, the percentage of student views that are at odds with the expert view. These two percentages will not necessarily sum to 100 due to the fact that students can always select a neutral response to any of the statements.

The statements of the survey are grouped into categories, with some questions residing in more than one of these categories. The categories are as follows: 'Personal Interest', 'Real World Connection', 'Problem Solving', 'Sense Making and Effort', 'Conceptual Understanding' and 'Applied Conceptual Understanding'. Problem solving has been further subdivided into Problem Solving 'General', 'Confidence' and 'Sophistication', giving eight categories in total. In order to allow the quality of student responses to be monitored there is a "fail-safe" question, which states *"We use this statement to discard the survey of people who are not reading the questions. Please select agree-option 4 (not strongly agree) for this question to preserve your answers"*. Approximately 4% (averaged over several years) of students who completed the survey during this study failed to choose the correct option and their survey responses were discarded. This is lower than seen in other published studies (Adams et al., 2006) and while it does not necessarily exclude all students who are not taking the survey seriously, it does allow the elimination of obviously unreliable data.

The CLASS survey was given to students, in paper form, in the first year physics class at the University of Edinburgh. They were asked to complete the survey both at the beginning and end of their first year (pre- and post- instruction). The pre-instruction data was collected in the first week of the first semester, before any teaching had taken place, with the post-instruction data being taken in the final week of teaching in the second semester before students depart on exam leave. All students were asked to take the survey, although participation was not compulsory and no course credit was awarded for completing the survey. Due to the nature of the study, only matched student surveys were used (meaning the same student had filled in both pre- and post-teaching surveys) for analysis so that changes in the attitudes of individual students could be traced. If a student had filled in either a pre- or post-instruction survey but not both their survey answers were discarded; this lead to approximately 40% of the collected surveys being discarded. When wishing to track the changes in student attitudes for subsections of a class it is necessary to be able to identify the specific students; to this end the surveys cannot be completed anonymously. Students are only asked to provide their student identification number, rather than their name, and all students were assured that their responses would be kept confidential and would not be shared with any of the instructors of the course (two of whom are authors of this paper) before anonymization.

As well as calculating overall favourable and unfavourable scores for the whole undergraduate class, the data was split in order to look at how the attitudes of subsections of the class as a whole changed over the course of first year teaching. Specifically, the data was split to look at the differences between male and female students and those differences between physics majors and non-majors. Table 1 shows the number of surveys collected per year along with the number in each of the populations studied in greater detail. In the case of the 2008-09 data the number of female and male students does not equal the total number of students due to the fact that gender data could not be found for two of the students after the data had been collected and the survey itself does not ask students to provide the information. The number of matched completed surveys for the non-majors is small compared to that for the majors. This could be due to several factors, including non majors choosing to take only one of the two semester long courses whilst the majors are required to take both. It could also be that the non-majors are less likely to engage with a voluntary survey they see as being ‘about physics’.

Statistical tests have been carried out to look for any variations in the responses between years (an independent 2-tailed t-test). No statistical differences were found between the two year groups either pre- or post-instruction, with the lowest significance corresponding to a p value of $p = 0.15$. This being the case, the data for the two academic years has been combined for analysis in this paper, giving a larger sample size and ensuring more confidence can be placed in the findings.

Table 1: Number of matched completed student surveys for the 2008-09 and 2009-10 academic years. Total cohort 2008/09 = 291, total cohort 2009/10 =304.

	2008-09	2009-10
All	147	134
Physics Majors	110	93
Non Majors	37	41
Male	112	108
Female	33	26

When any differences between data points, (either pre- and post-instruction for the same group or one group to another) were detected, statistical tests were carried out to establish whether any of these differences were significant. As above, the tests used were t-tests. As no predictions about the direction of the differences between group cohorts had been made prior to data collection, a two-tailed independent t-test for samples with unequal variance was used when comparing one cohort to another. When looking at the changes pre- and post-instruction for the same group of students a paired t-test was used.

Results

The survey allows the responses to be considered for both favourable and unfavourable responses; only the favourable responses are presented in this paper for brevity. Despite the presence of the 'neutral' option, nevertheless it was found that while the specific details of the unfavourable responses differed they followed the inverse pattern of the favourable, with groups who scored highly on the favourable percentage scoring a low percentage unfavourable and vice-versa.

The results are presented in three sections: firstly the results for the class as a whole, followed by the results when split to look at the differences between majors and non-majors and, finally, the differences between male and female students. We will then go on to look more deeply into the differences highlighted by the overall results by looking at the results of individual categories from the CLASS survey.

Results of whole class

As shown in Figure 1, the students are entering the degree program with high levels of expert-like thinking, with 71% (SEM 1%) agreement with the expert responses; here, as in all subsequently quoted values, the bracketed figure represents the standard error on the mean, calculated by dividing the standard deviation of the cohort responses by the square root of the number of responses in the sample.

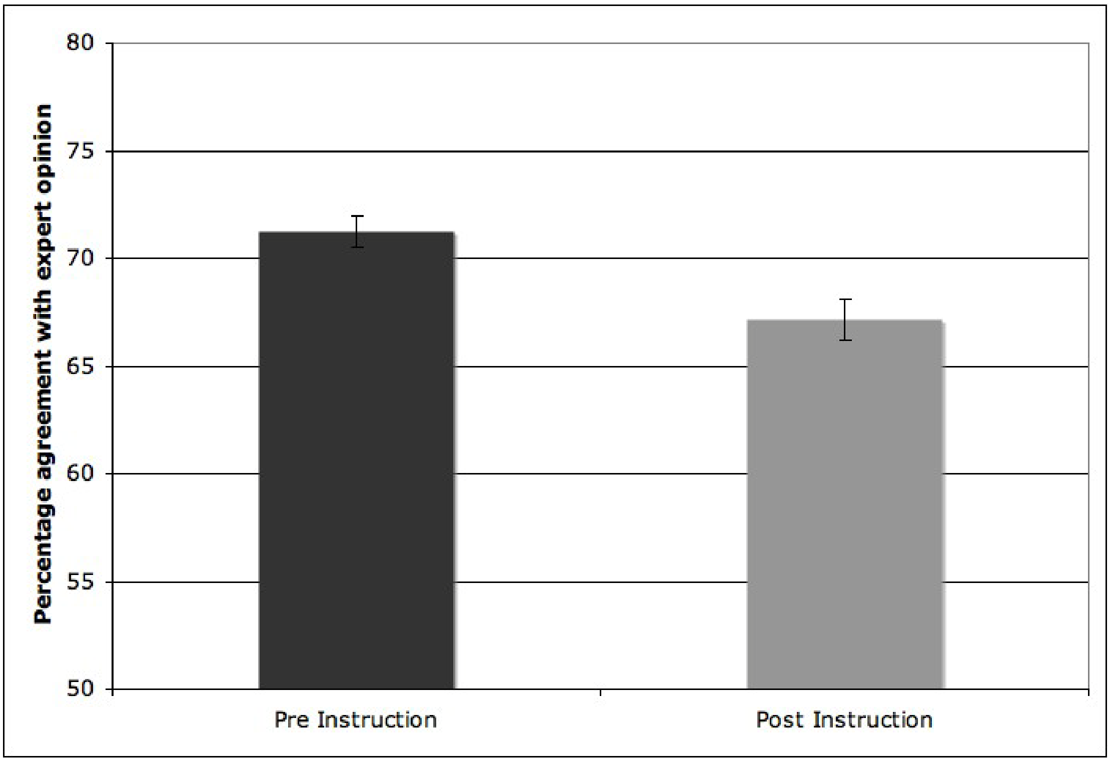

Figure 1: Percentage of favourable expert-like thinking pre- and post- first year instruction. The dark grey bar indicates pre-instruction and the light grey post-instruction. Error bars represent the standard error on the mean. N=281 for both pre and post instruction data

After the period of instruction, the students exhibit a reduction in expert-like thinking, with a class average of 67% (SEM 1%) expert-like thinking; this decrease is significant (*t*(280)=5.16, *p*<0.001, d=0.29). The drop is not unexpected and is in line with previous studies, which suggest that unless a curriculum is designed to specifically address student epistemologies, a drop in expert like thinking will be seen (Redish & Hammer, 2009). It is, however, worth noting that the students are coming in with relatively high levels of expert-like thinking compared to physics students in North America, with their level of expert-like thinking approximately 6% higher pre-instruction than those seen by the CLASS survey authors (Adams et al., 2006) and while there is a significant drop, the students are still remaining at high levels and record approximately an 8% higher percentage than those in the same paper. This pattern is repeated in a study from outside the US where students in Saudi Arabia also show a drop in expert-like thinking post instruction (Alhadlaq et al., 2009). Therefore while the students at the University of Edinburgh begin and end their first year instruction with higher levels of expert-like thinking, the overall drop is of approximately the same magnitude as those seen in international studies.

Physics majors and non-majors

By choosing to filter the results of the class by one factor only, whether they intend to study for a physics degree, the data is split into two distinct groups, labeled as physics majors and non-majors. Figure 2 shows the pre- and post-instruction percentages of expert-like thinking for both majors and non-majors.

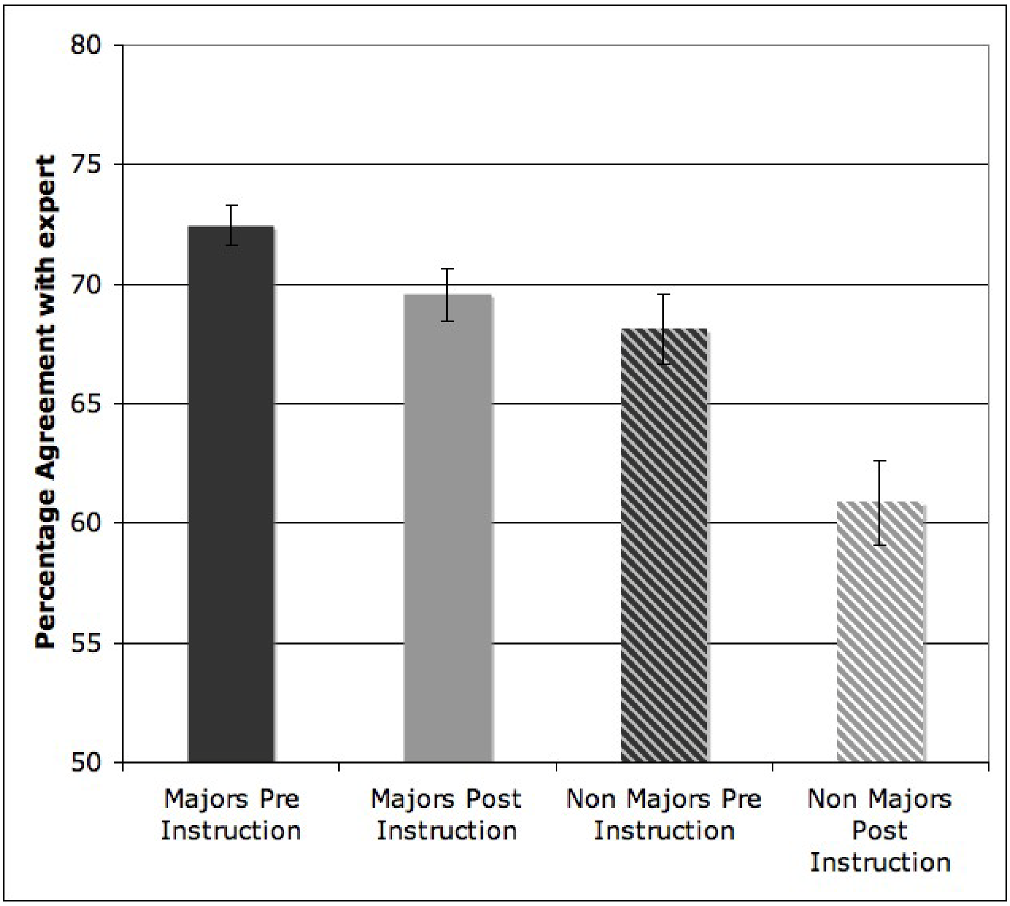

Figure 2: Percentage of favourable expert-like thinking for physics 'majors' (N=203) and 'non-majors' (N=78) both pre- and post- first year instruction. The dark grey bar indicates pre-instruction and the light grey post-instruction. Filled bars have been used for the majors and hatched bars for the non-majors. In all cases error bars represent the standard error on the mean.

There are several points of interest emerging from the results in this figure: firstly, the majors and non-majors are starting from different levels of expert-like thinking; this difference is 4% pre-instruction and is statistically significant ($t(127)=2.42$, $p=0.017$, $d=0.34$). We recall that all students must meet the same minimum entrance requirements and have carried out the same level of high-school physics as the physics majors, the only difference between the two groups is the intended degree course of study. This difference in background distinguishes the students in this study from those in other studies that have looked at the differences between majors and non-majors. However the results found remain in line with those seen in previous studies where, for example, engineering students have been shown to have significantly less expert-like views than physics majors (Gire et al., 2009) and those intending to study physics degrees are seen to be more expert-like than those who are not (Perkins & Gratny, 2010).

The other point of interest is the magnitude of the decrease in expert-like thinking. The majors show a relatively small drop in agreement from the expert opinion going from 72% (SEM 1%) pre instruction to 70% (SEM 1%) post teaching. In contrast the non-majors show a change of 7%, going from 68% (SEM 1%) pre-instruction to 61% (SEM 2%) post. The change for the majors is significant ($t(202)=3.13$, $p=0.002$, $d=0.21$), as is the change for non-majors, with the change for non-majors recording a medium to large effect size ($t(77)=4.73$, $p<0.001$, $d=0.51$).

In the light of these differences between the majors and non-majors, analysis has been carried out to look for differences in the educational background of the physics majors and non-majors. All qualifications in the United Kingdom, regardless of whether they were gained in Scottish or English schools, are assigned to a national tariff of points by the Universities & Colleges Admissions Service (UCAS) (UCAS, 2010). By using this points system the qualifications of all the students can be compared without complication as to the awarding body. No statistically significant difference is seen between the mean tariff for entry qualifications of the majors and non-majors ($t(223)=1.28$, $p=0.20$, $d=0.09$).

In addition the correlation between physics background of the students and CLASS score has been examined. It does not appear that previous physics achievement is a strong predictor of CLASS score, as illustrated in Figure 3.

Male and female Students

The whole set of data was also split to look at the differences between male and female students. Figure 4 shows the percentage of expert-like thinking for each of the two groups.

There is a key difference between the subgroups in Figures 2 and 4. Unlike the majors and non majors there is no statistically significant difference between the male and female students before instruction ($t(94)=1.35$, $p=0.18$, $d=0.19$): The male students record 72% (SEM 1%) expert-like thinking before instruction and the female students 69% (SEM 2%). However after instruction there is a significant difference between the two groups with the male students scoring 68% (SEM 1%) and the female students 63% (SEM 2%). The two groups are now statistically different to each other ($t(82)=1.99$, $p=0.05$, $d=0.32$), suggesting that the first year experience has a greater impact on the attitudes of the female students.

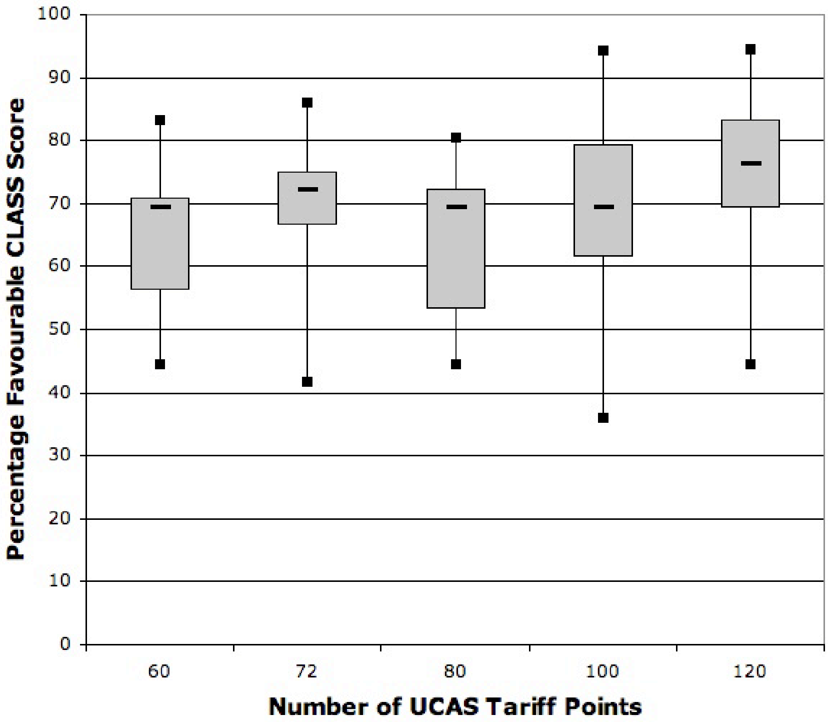

Figure 3: Comparison of number of UCAS points earned at school, with overall favourable CLASS score. 60 UCAS points represents a Grade B at Higher or a Grade D at A-Level. 120 UCAS points represents a Grade A at either A-Level or Advanced Higher (Values correct for university entry to 2010) (UCAS, 2010). The dark line on each box represents the median for each grouping.

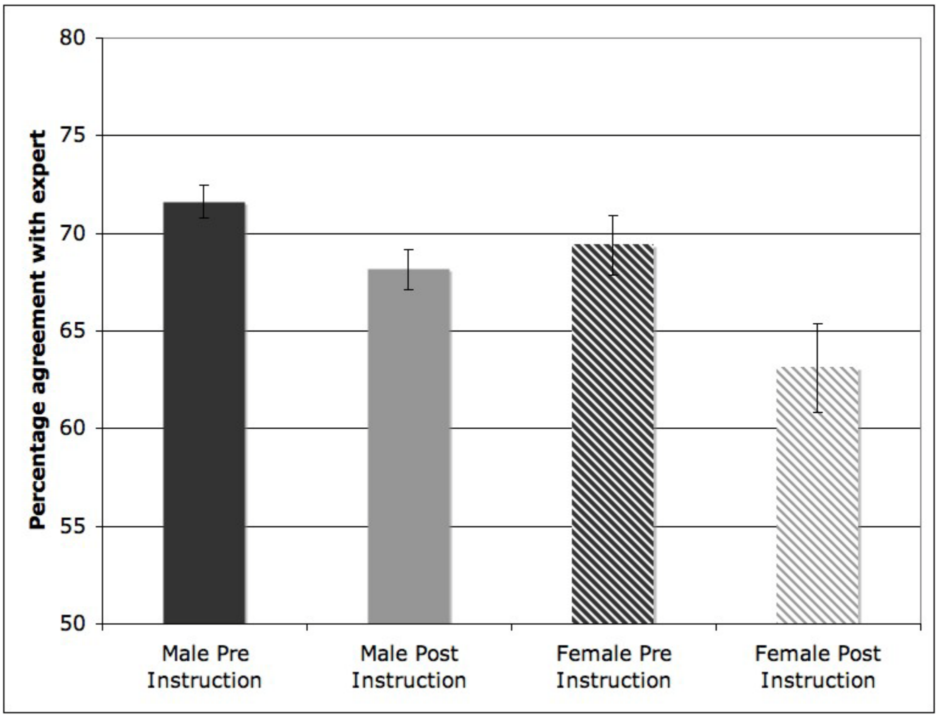

Figure 4: Percentage of favourable expert-like thinking for male physics students (N=220) and female physics students (N=59) both pre- and post- first year instruction. The dark grey bar indicates pre-instruction and the light grey post-instruction. Filled bars have been used for the male students and hatched bars for female. In all cases error bars represent the standard error on the mean.

Second Tier Differences

As well as looking at the overall percentages for the whole first year class and sub-populations, further analysis has been carried out to look at the differences in the eight separate CLASS categories described previously. In this paper these are referred to as the 'second tier' categories as they give a greater understanding of what is causing the changes in overall favourable percentage scores. They allow us to look at differences between the groups in specific areas, as well as identify which specific categories have undergone the biggest changes. The favourable percentages for physics majors and non-majors, for all categories, are seen in Table 2.

Table 2: Percentage favourable scores for all 8 CLASS categories for physics majors and non-majors both pre and post-instruction. Numbers in brackets represent the standard error on the mean.

Category	Majors Pre	Non Majors Pre	Majors Post	Non Majors Post
Personal Interest	78(1)	72(3)	73(2)	61(3)
Real World Connection	75(2)	72(3)	72(2)	63(3)
PS General	81(1)	78(2)	78(2)	68(2)
PS Confidence	78(2)	77(3)	75(2)	66(3)
PS Sophistication	76(2)	72(3)	69(2)	60(3)
Sense making/ effort	82(1)	77(2)	77(1)	67(3)
Conceptual Understanding	76(1)	68(2)	71(2)	60(3)
Applied Conceptual Understanding	63(2)	58(3)	58(2)	49(3)

The per-category results show a very clear picture, with the physics majors scoring either more highly or the same as the non-majors in all eight categories prior to University instruction. Two of the eight categories, 'sense-making and effort' and 'conceptual understanding' show a statistically significant difference between majors and non-majors pre-instruction, ($t(123)=2.18$, $p=0.031$, $d=0.31$) and $t(133)=2.97$, $p=0.004$, $d=0.41$) respectively. Post university instruction, the majors score more highly in all eight categories with a statistically significant difference between majors and non-majors in all categories, at the $p \leq 0.05$ level. It is clear from the results that the majors and non-majors have different attitudes towards physics study. We have recently conducted a similar study which looks at the attitudes of high-school students and the differences in expert-like thinking between a class of students taking high schools physics and those from the same group who are also intending to study physics as an undergraduate degree (Bates et al., 2011). A significant difference is seen with those intending to study physics scoring a much higher level of expert-like thinking, suggestive of a selection effect. The pattern seen here may reflect the fact that we are seeing those students from the high school classes with lower levels of expert-like thinking taking physics as a non-major at university. Previous work on the differences between physics majors and engineers (Gire et al., 2009) has shown that while physics majors score more highly in expert-like thinking these differences can not be solely accounted for by differences in scores in the 'Personal Interest' category, as is also illustrated in this study.

The situation is far less well defined when looking at the gender differences per category, the results of which are shown in Table 3. Here we see that prior to University teaching, there are no categories where there is a statistically significant difference between male and female students. Post instruction female students have shown large decreases in all categories. The size of these percentage decreases is much larger than for the male students, with the largest female decreases being in ‘Real World Connection’ and ‘Conceptual understanding’, both of which decreased by 12%. The largest decrease for male students was in ‘Problem Solving Sophistication’, which fell by 7%. Three of the post instruction differences between the male and female students are statistically significant at $p \leq 0.05$: ‘Problem Solving Sophistication’ ($t(80)=2.34$, $p=0.022$ $d=0.38$), ‘Real World Connection’ ($t(84)=2.10$, $p=0.039$ $d=0.33$) and ‘Applied Conceptual Understanding’ ($t(79)=2.01$, $p=0.048$, $d=0.33$). Similar results have been seen in studies focusing on gender differences in students (Kost, Pollock & Finkelstein, 2009), which have seen female students with similar scores to male students in the categories pre-instruction, but experiencing larger, negative shifts post-instruction, with significant shifts in ‘Problem Solving’ and ‘Conceptual understanding’ categories.

Table 3: Percentage favourable scores for all 8 CLASS categories for male and female physics students both pre and post-instruction. Numbers in brackets represent the standard error on the mean.

Category	Male Pre	Female Pre	Male Post	Female Post
Personal Interest	77(2)	73(3)	71(2)	65(3)
Real World Connection	74(2)	75(3)	71(2)	63(4)
PS General	81(1)	78(3)	77(1)	70(3)
PS Confidence	79(2)	72(3)	74(1)	66(3)
PS Sophistication	76(1)	69(3)	69(2)	58(4)
Sense making/ effort	80(1)	83(2)	74(1)	75(3)
Conceptual Understanding	74(1)	75(3)	69(2)	63(3)
Applied Conceptual Understanding	62(2)	60(3)	57(2)	49(4)

The data has not been further subdivided to look at the differences between female and male majors and non-majors due to the small sample size of female students. This will be carried out as future work after further data collection has occurred in order to increase the sample size.

Conclusions

The change in student expert-like thinking during the first year of university instruction has been well documented in publications from North America and, increasingly, other academic institutions around the world. The results presented in the previous sections show that during year 1 students studying at the University of Edinburgh also undergo a decline in expert-like thinking in line with previous studies. This is despite the course being of a ‘reformed’ workshop-based format that is successful and effective by any other measure. Previous studies have shown that reformed teaching practice alone is not enough to increase student attitudes towards study, instead gains are only seen when student epistemologies are specifically targeted.

The students in this study have high levels of expert-like thinking, compared to results in previous studies both pre and post instruction. The size of the decrease is comparable to those seen in previous studies, suggesting that the high levels of expert-like thinking post-instruction are due to the high starting position of the students.

Looking at the undergraduate class in more detail, by comparing the differences between physics 'majors' and 'non-majors', we have seen that those students intending to complete a physics degree come in with higher levels of expert-like thinking than those students taking physics as an outside course. We have also seen that these physics majors decline less in their levels of expertise over the period of first year instruction. Looking at the second tier of information we see that there is a marked difference between majors and non-majors in all eight of the CLASS categories, with the physics majors consistently scoring more highly both pre- and post-instruction. These differences exist despite the fact that the non-majors have the same previous qualifications and experience as the majors and have freely elected to take the course. The only distinguishing factor between the two groups is the intention to study for a physics degree, raising the question as to what prior experiences have shaped the student attitudes?

There are also differences between male and female physics students post instruction, although, unlike the physics majors and non-majors, there is no obvious overall difference in expert-like thinking between male and female students before university teaching. When looking at the 2nd tier category percentage scores there are no categories that show a statistically significant difference prior to university teaching. This is not the case post first year instruction with the male students scoring much more highly than their female peers. On a category per category basis the male students now record a higher percentage in three of the eight of the categories with the largest decline seen by female students almost double the largest for males.

It is possible the decrease in student expertise may be linked to a drop in confidence over the first year of teaching. This drop in confidence is detailed in Perry's model of learning (Perry, 1970) which details nine stages of intellectual development of university students. These nine stages can be grouped into 4 categories known as 'dualism', 'multiplicity', 'relativism' and 'commitment'. Most students will begin university in the first stage of intellectual development, dualism, which relates to the idea that there is only one correct answer and it is the job of the learner to gain the right answer from the instructor. Multiplicity is an extension of dualism where students extend their horizons to incorporate the idea that an answer can be not yet known, as well as right or wrong. The step to the third stage, relativism, where students realise that knowledge is relative and context dependent, is seen as a very large step of progress in development. It is at this stage that students can experience a loss of confidence and step back to previous levels, with a cyclical process established where some students may never reach the uppermost categories. It could be that the drop in expert-like thinking seen at the end of first year instruction relates to a step back to a previous learning stage.

The findings in this paper have potential implications for the way university teaching of physics is structured. The nature of the university system at the University of Edinburgh leads to a first year class highly dissimilar to those outwith Scotland, with physics non-majors possessing near identical backgrounds and final high school grades to the physics majors. In addition, almost all of the non-majors are present in the class through personal choice (rather than being compelled by the requirements of their own degrees). Thus, the only substantial distinction between majors and non-majors is the intention to complete a physics degree: however, we still see a marked difference in response to a year's physics instruction by these sub-cohorts. Similarly, the male and female sub-cohorts are also quite distinct in their change in expert-like thinking. Incorporating research-based instructional strategies alone does not lead to enhanced attitudes and beliefs after a year of instruction, though curriculum reforms that directly address attitudes and beliefs have been shown to have positive effects in other studies. An interesting avenue for future work would be to explore the self-efficacy of students and investigate the extent to which personal characteristics affect student attitudes towards study.

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