

Correlating Student Attitudes With Student Learning Using The Colorado Learning Attitudes about Science Survey

K. K. Perkins, W. K. Adams, S. J. Pollock, N. D. Finkelstein and C. E. Wieman

*Department of Physics
University of Colorado, Boulder*

Abstract. A number of instruments have been designed to probe the variety of attitudes, beliefs, expectations, and epistemological frames taught in our introductory physics courses. Using a newly developed instrument – the CLASS¹ – we examine the relationship between students’ attitudes and beliefs and other educational outcomes, such as conceptual learning and student retention. We report results from surveys of over 750 students in a variety of courses, including several courses modified to promote favorable student attitudes. We find positive correlations between particular student attitudes and conceptual learning gains, and between student retention and favorable attitudes and beliefs in select categories. We also note the influence of teaching practices on student attitudes.

INTRODUCTION

In addition to the traditional content within any course, there are extensive sets of attitudes and beliefs about science that are taught to our students. How we conduct our class sends messages about how, why, and by whom science is learned. Such messages are being studied with the goal of developing more expert-like views on the nature and practice of science in our students.^{2,3,4}

Over the last decade, physics education researchers have used several survey instruments to measure these attitudes and beliefs.^{5,6,7} Data have shown that, traditionally, student attitudes become more novice-like over the course of a semester.⁵ Even in courses using reformed classroom practices successful at improving student conceptual learning of physics, student attitudes tend not to improve.⁴ Some success has been achieved, however, in courses specifically designed to attend to student attitudes.²

With these new measures of student attitudes and beliefs about physics and about learning physics, the question emerges as to how these factors impact and are impacted by both students’ pursuit of physics study and their mastery of the content.⁸ In this paper, we begin to examine the relationships among these different aspects of student learning. We look at: 1) the influence of teaching practices on student attitudes; 2)

the relationship between students’ attitudes and beliefs about physics and their decisions about which physics course to take and whether to continue on in physics; and 3) the relationship between student attitudes and beliefs about physics and their conceptual learning in the physics course.

DATA

The Colorado Learning Attitudes about Science Survey (CLASS)¹ was used to measure student attitudes both at the start (pre) and end (post) introductory physics courses. The newly-developed CLASS survey builds on the existing attitude surveys (MPEX⁵, VASS⁶, EBABS⁷). The details of the design and validation of the CLASS are reported by Adams et al.,¹ but in brief, the survey consists of 38 statements to which students respond using a 5-point Likert-like scale. The ‘Overall’ favorable attitude score is measured as the percentage of questions the students answer in the favorable sense, e.g. as an expert-physicist would. The ‘Overall’ unfavorable score is similarly determined. The survey is used to measure specific attitude and belief categories by looking at subsets of questions. Here, we include measurements of the following facets: Concepts (physics is based on a conceptual framework), Math (equations represent concepts), Metacognition (reflection, reasoning, sense making), Reality World (physics describes the world), and Reality Personal (I think about physics in my life).

For looking at the influence of teaching and at student's course selection and retention, we use data from six courses. These courses range in size (less than 40 to over 600 students), student population (non-science majors; pre-meds; physics, chemistry, and engineering majors), and school setting (from a large state research university (LSRU) to a mid-size multipurpose state university (MMSU)). Table 1 lists the courses as well as the other data available for each course.

For looking at the correlation with conceptual learning, we focus on the LSRU's large calculus-based course in Spring 2003. The large number of the students allows us to examine sub-groups of students and retain good statistics. The structure of this course included multiple reforms designed to improve student learning and attitudes, including interactive engagement in lecture, tutorial-style recitations, and an emphasis on conceptual understanding. In addition, the development and application of expert-like attitudes and approaches to problem solving were emphasized across the course components. For a detailed description of the reforms and an analysis of the contribution of various reforms to learning see Pollock.⁹

RESULTS AND DISCUSSION

Influence of teaching practices. In Table 1, we show the average pre- and post- 'Overall' favorable attitude for the six introductory physics course. In bold, we see a decline in attitude of 9% for the Alg-I and 10% for the Calc-I courses taught at MMSU. While the Alg-I course was traditionally taught, the Calc-I course was taught using interactive engagement methods; however, neither course specifically attended to improving student attitudes. These declines are consistent with those observed in similar courses.⁵ In contrast, all of the courses in this study taught at LSRU, although constrained to a large lecture format, incorporated teaching practices aimed at improving student attitudes and resulted in increases of 1-2% in Overall

attitude (a statistically significant shift for the Calc-I, Spring 2004 course; N=416).

Course selection and retention. The courses listed in Table 1 represent a range of commitments to the study of physics. We see that the students' *incoming* favorable attitude on the 'Reality Personal' category increases with the level of the physics course in which students enrolled. The non-science majors average only a 44% favorable attitude while the average for the course for physics majors is 71%. Thus, students who make larger commitments to studying physics tend to be those who identify physics as being relevant to their own lives – as measured by 'Reality Personal'.

In addition, we see that the non-science majors who chose to continue and take the second term had significantly more favorable 'Overall' and 'Reality Personal' attitudes than those who did not, with the average attitudes increasing by 15% and 17%, respectively. For the MMSU Alg-I course, a significant number of students dropped during the term. The students who completed the course had substantially more favorable 'Reality Personal' attitudes initially (61%) than those who dropped (39%). These two pieces of data strongly suggest a link between retention of students (both within and across courses) and students' favorable attitudes.

Attitudes and Conceptual Learning. The LSRU's large calculus-based courses were highly successful at achieving their goal to improve student learning.⁹ On two standard exams for measuring conceptual learning, the students achieved median normalized gains of 0.67 on the FCI¹⁰ (Fall 2003) and 0.76 on the FMCE¹¹ (Spring 2004). While the median gain was quite high, some students had significantly smaller learning gains and a large number of students had much higher learning gains. With pre/post CLASS and FMCE data on 331 students from Spring 2004, we are able to explore the relationship between students attitudes and their learning gains.

TABLE 1. Correlations between favorable 'Reality Personal' and physics course selection

Course Type	School Type/Term	Dominant student population	# of students w/ CLASS	Learning gains	Overall %favorable ^s		Reality Personal %favorable on Pre-test (uncertainty)
					Pre	Post	
Non-Sci-I	LSRU/Fa03	non-sci	77		56%	57%	44% (4%)
Non-Sci-II	LSRU/Sp04	non-sci	34		71%	73%	61% (5%)
Alg-I	MMSU/Fa03	pre-meds	36	g_FCI=0.13	60%	51%	61% (5%)
Calc-I	LSRU/Fa03	engineers	174	g_FCI=0.67	63%	65%	63% (2%)
Calc-I	LSRU/Sp04	engineers	416	g_FMCE=0.76	64%	66%	64% (1%)
Calc-I	MMSU/Fa03	physics maj	41	g_FCI=0.35	64%	54%	71% (5%)

I=1st semester, II=2nd semester; ^s typical standard deviation for 'Overall' is ~16%.

TABLE 2. Correlations between attitudes and learning

Attitude category	Correlations of FMCE gain* (Sp04)	
	with Pre-attitude	with Post-attitude
Overall	0.22	0.33
Concepts	0.18	0.33
Metacognition	0.21	0.34
Math	0.18	0.23
Reality World	0.05	0.15
Reality Personal	0.04	0.18

* for students with FCE pre-test < 20 and FMCE pre-test < 60.

In Table 2, we show the correlations between students attitude and their normalized learning gain. We limit these to the 90% of the students who had FMCE pre-test scores < 60 (Thornton’s level of conceptual mastery using his grading method)¹¹. The correlations in the various attitude categories range from 0.04 to 0.22 for pre-attitudes and 0.15 to 0.34 for post-attitudes. Many of these correlations are larger than the correlations of learning gain with homework, attendance, and a math pre-test, which are all 0.22 or lower.⁹ In looking at these correlations, we see larger correlations with post-attitude than pre-attitude in all attitude categories. In addition, the categories of ‘Concepts’ and ‘Metacognition’ are better correlated with learning gains than ‘Reality World’ or ‘Reality Personal’. It makes sense that expert attitudes in these former two categories are more important to the form of learning measured by the FMCE.

Example of data underlying these correlations are revealed in Figure 1 where we show students average pre- and post- attitudes as a function of normalized learning gain for the ‘Overall’ and ‘Metacognition’ categories. Two clear trends emerge: (1) students with higher conceptual gains tend to have more favorable attitudes in these categories and (2) students in the lowest gain category tend to retreat in attitudes, while higher performing students tend to post gains in attitudes. Similar trends are observed for other categories.

It is important to note that the correlations between attitude and learning gain listed in Table 2 apply to this course with its teaching practices, student population, and curriculum and with its choice of instrument for measuring conceptual learning. Changes to any of these elements can effect the correlations with attitudes. Analysis of the observed affect can then help interpret the meaning of the change and provide some more insight into the relationship of student attitudes and learning. For example, the Fall 2003 LSRU course had the same instructor (Pollock) using the same teaching practices and materials, but using a different measure of conceptual learning gain (the FCI). While the data *do* show the same general trends as observed in Figure 1, they show somewhat stronger correlations between learning gain and both pre and post attitudes.

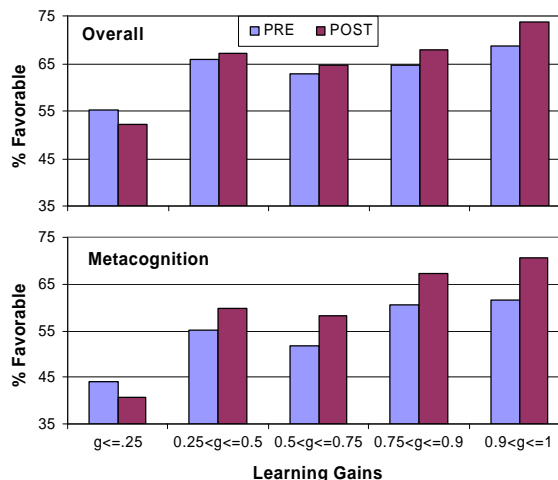


FIGURE 1. Average pre- and post- attitudes vs. conceptual learning gain.

In addition, some categories which show relatively weak correlations here show stronger correlations with the FCI learning gain, and vice versa. These differences likely reflect the differences in the learning measured by the two instruments.¹¹

The correlations reported here are between *individual* attitude categories and learning gain. If multiple categories contribute to improved learning, it is likely that a *weighted combination* of categories would result in significantly higher correlation coefficients and is a topic of future analysis. Higher correlations may also result from the ongoing refinement of the CLASS questions and categories to better probe attitudes.¹

As a start to understanding possible cause and effect, we have looked further at the relationship between pre-attitude and learning gain and the meaning of the observed correlation of 0.22. In Figure 2, we have binned the students by their incoming overall attitude and plotted the percent of students within each attitude bin who achieve learning gains of greater than 0.8, 0.8 to 0.3, and less than 0.3. We see that over 50% of the students with favorable pre-attitudes of 80-100% achieve learning gains in excess of 0.8 and that this percentage decreases for each successive attitude bin while the percentage of students with learning gains less than 0.3 increases. These data suggest that students’ attitudes about science when they enter a course influence their conceptual learning. Of course, we cannot rule out the alternative conclusion that other factors are simultaneously influencing both students’ incoming attitudes and their conceptual learning.

To look how learning is impacting or impacted by changes in students’ attitude over the course of the term, we select a subgroup of students with nearly

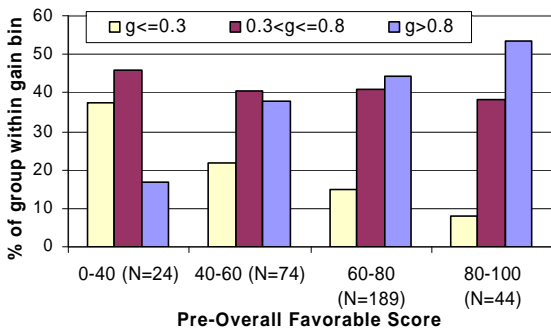


FIGURE 2. Conceptual learning gain vs. Pre- 'Overall' attitude.

identical incoming attitudes and look at the connection between their *shift* in attitudes and their learning gain. We select students with incoming overall attitudes of between 60 and 70% favorable (½ of the 60-80% bin above). For this group of students, we separated students by gain and looked at the percentage of students within each gain group that had substantial positive and negative shifts in their attitudes. The results are plotted in Figure 3. Here we see a positive relationship between occurrence of favorable attitude shifts over the course of the term and higher learning gains. This relationship is also seen in the increase of the correlation between 'Overall' attitude and learning gain from 0.22 for pre-attitudes to 0.33 for post attitudes (Table 2). We cannot determine whether the shift in attitude promoted (deterred) learning or whether the learning/achievement promoted (deterred) changes in attitude. However, given the evidence in Figure 2 that pre-attitudes influence learning gains, it is likely that improvements in attitudes over the course of the term will also positively impact learning gains.

CONCLUSION

Our analysis of students' attitudes and beliefs measured using the CLASS suggests that attitudes play a role both in the physics courses students choose to take and in their retention within those courses and in the discipline. In addition, we observe positive correlations between student attitudes and conceptual learning gains. We see that students who come into a course with more favorable attitudes are more likely to achieve high learning gains. We also find that students who learn more tend to be those who have more positive shifts in attitudes over the course of the term. Thus, it is reasonable to believe that attitudes and beliefs are a leading factor in student learning. These findings inform the importance of attending to students' attitudes and beliefs in our classrooms. In our work, we found that it is possible to create environments, even in large lecture courses, that support im-

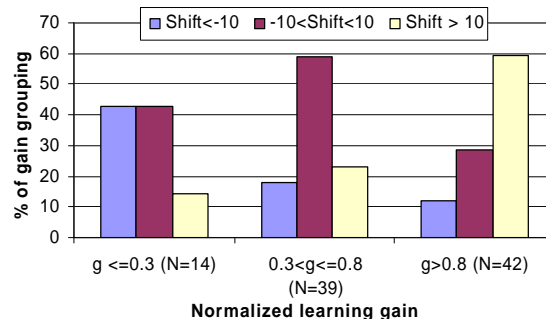


FIGURE 3. Attitude shift vs normalized learning gain

proved student attitudes and that this specific attention can avoid the common decline in attitudes and even result in statistically significant improvements.

ACKNOWLEDGMENTS

The authors thank NSF for providing the support for this work. We are also very grateful to all of the instructors who generously agreed to administer the CLASS in their courses. We also give thanks to all the members of the Physics Education Research at Colorado group for many valuable discussions.

REFERENCES

- 1 W. Adams et al., "Design and Validation of the Colorado Learning About Science Survey" in review for Proceedings of the PERC 2004, Sacramento, CA. <http://cosmos.colorado.edu/phet/survey/CLASS/>
- 2 D. Hammer, *Am. J. Phys.* 68, S52-S59 (2000).
- 3 A. Elby, *Am. J. of Phys* 69(7) (2001).
- 4 Redish, *Teaching Physics with Physics Suite*, Wiley 2003
- 5 Redish, E.F., Saul, J.M. and Steinberg, R.N. (1998). *Am. J. of Phys*, 66, 212-224.
- 6 Halloun, I. A. "Views About Science and Physics Achievement: The VASS Story." In *The Changing Role of Physics Departments in Modern Universities: Proceedings of the ICUPE*.
- 7 Elby, A., Epistemological Beliefs Assessment for Physical Science <http://www2.physics.umd.edu/~elby/EBAPS/home.htm>
- 8 A. Schoenfeld, "What's all the fuss about metacognition," in A.Schoenfeld, *Cognitive science and mathematical education*. Philadelphia: Lawrence Erlbaum. 1987.
- 9 Pollock, S. "No Single Cause: Learning Gains, Student Attitudes, and the Impacts of Multiple Effective Reforms" in review for Proceedings of the PERC 2004, Sacramento, CA.
- 10 Hake, R., *American Journal of Physics* 66, 64-74, (1998)
- 11 Thornton, R., Sokoloff, D., *Am. J. Phys* B66(4), 338-352, 1998, also Thornton, R., Kuhl, D., Cummings, K., Marx J., "Comparing the FMCE and the FCI", unpublished.