

Attitudes of Undergraduate General Science Students Toward Learning Science and the Nature of Science

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Abstract. We investigated general science students' attitudes regarding the acquisition of scientific knowledge and the nature of science by administering a 32-item attitudinal survey. To assemble a representative array of epistemological attitudes at our institution and to determine the impact of instruction, we administered this survey to over 250 students from 19 sections of three general science courses. We characterized the instructional styles for each course using three broad categories: *Traditional*, *Transitional*, and *Learning-centered*. This paper focuses on the impact those different instructional styles had on students' epistemological beliefs.

INTRODUCTION

It has been made clear to the physics education community that confronting students' misconceptions, alone, should not constitute the entire instructional goal of a well-intentioned curriculum. It is also important to positively affect students' feelings about learning science and the nature of scientific inquiry.[1,2] For example, Redish et al. demonstrated that physics courses well-designed to promote conceptual understanding only weakly influence students' epistemological outlooks.[3] Elby showed that achieving attitudinal gains is possible in High School physics, but curricular materials must be designed to address epistemology.[4]

In this paper we discuss the epistemological effects of various instructional styles on students in general sciences courses, the majority of whom are non-science majors. This population is interesting in that it is underreported in the literature; references 1 and 3, for example, report on attitudes in physics classes. Yet, hundreds of thousands of undergraduates enroll in general science courses each year.[5] This motivated us to determine if trends reported for physics students hold for general science students, too.

Laura Lising and Andy Elby, with input from Priscilla Laws and David Jackson, constructed the survey instrument we used for this study by combining and modifying items from the Epistemological Beliefs

Assessment for Physical Science (EBAPS) and the Maryland Physics Expectations Survey (MPEX). (These two instruments have a documented history.[6,7]) The survey contains 22 five-point, Likert-scale (strongly disagree – strongly agree) items; five multiple-choice items; and five short dialogues requiring the examinee to side with one person's opinion or the other. The survey has a dichotomous scoring rubric; if the examinee's response matches the favorable (most expert-like) response, the item is graded 1, otherwise 0. (For all but one item there are two favorable responses.) An examinee's overall score is the percentage of his/her favorable responses.

The survey authors largely constructed their tool around five epistemological clusters – the organization of scientific knowledge (*Structure* cluster), accruelement of new knowledge (*Nature of Learning* cluster), relationship between classroom science and the real world (*Reality* cluster), evolution of scientific knowledge (*Evolving* cluster), and connections between assiduity and understanding (*Source* cluster). The survey authors omitted six of the 32 items from all clusters, but the accompanying spreadsheet, designed to facilitate grading and analysis, left open the possibility of adding items to and removing items from clusters. To improve the robustness of the clusters, we removed the two-item cluster referred to as *Concepts* and moved those items to the *Structure* and *Nature* clusters. We also added three items to the *Source* cluster and one to *Reality*. In the end we had seven

items each in *Structure* and *Nature*, six in *Reality*, two in *Evolving*, and seven in *Source*. To determine the cluster score for a group, we calculated the group's average for each item in that cluster and then averaged those items. (Note: Scores for the *Evolving* cluster are difficult to compare because it consists of only two items and one of those is the only item with a single favorable response. As such, the group average on that item tends to be low, which suppresses the *Evolving* cluster's average.)

POPULATION AND COURSE STRUCTURES

McDaniel College is a selective, residential, four-year, liberal arts institute, with an undergraduate population of about 1600 students. The college requires all students to complete two courses under the heading of Natural Science and Mathematics. As such, well over 80% of the students enrolled in our department's General Science offerings are non-science majors fulfilling graduation requirements.

We surveyed students' attitudes from the Spring of 2002 through the Spring of 2004 in 18 sections of three General Science courses – *A World of Light and Color*; *Astronomy*; and *Sound, Music, and Hearing*. (These classes typically have about 15 to 20 students enrolled.) We matched pre-test/post-test data for 255 students. We also have post-test data from an additional section of *Astronomy*.

For the purposes of this paper we broadly characterize these courses into three categories, which depend on the percentage of class time devoted to some sort of research-based curricular materials aimed at addressing conceptual understanding, not developing epistemology.

- *Traditional* courses have little or no research-based pedagogy. Class time is largely filled with lectures and demonstrations; slides and videos; and laboratories that follow prescribed instructions, some of which are computer-based. Traditional classes had some group work. All of the *Astronomy* sections with matched pre-test/post-test data fell into this category.
- *Transitional* courses have approximately half of the classroom time devoted to research-based activities. These activities come in several forms including exploratory laboratories, activities modeled after *Interactive Lecture Demonstrations* [8], and group worksheets designed to reinforce relevant physical concepts and build numeracy. The other half of the time is lecture-based. One section of *A World of*

Light and Color and all of the sections of *Sound, Music, and Hearing* were *Transitional*. (We will also present post-test data for a section of *Astronomy* that was *Transitional*.)

- *Learning-centered* courses incorporate research-based curricular materials of the kind discussed above in every class meeting, and lecture time is minimized. *A World of Light and Color* was the only course that fit into this category.[9]

Each course had traditionally-graded assignments, including several homework sets, quizzes, tests, projects, and a final exam. None of the graded assignments were intended to foster or reinforce students' epistemologies.

ANALYSIS

Looking at the overall attitudinal gains achieved by our population, we see that for the entire group of matched pre-tests and post-tests (N = 255) the average score on the pre-test was 57% and the post-test average was 55%. (This is not a statistically significant drop; nevertheless, we hoped for an overall increase.) Only the decrease in the *Source* cluster's score was statistically significant. Table 1 shows the matched data set for the clusters. (In all of the tables, overall and cluster scores are presented as averages of the favorable responses. We do not report the standard deviations for any averages. It suffices to say that the deviations are quite large, typically ranging from 10 to 20%. None of the comparisons we made differed by more than one standard deviation.)

TABLE 1. Cluster Analysis for all students. Statistically significant ($\alpha = 0.95$) changes are in boldface.

Cluster	Pre	Post
Structure	46	48
Nature	54	52
Reality	70	68
Evolving	40	44
Source	69	62

We realized that combining all of the students together masks the effects of different instructional styles on students' attitudes. To reveal such effects, we divided students by the type of instruction they encountered. (See Table 2.) This showed that the *Learning-centered* and *Transitional* courses resulted in no instructionally significant change in the overall scores. However, the decrease in the *Traditional* courses is instructionally significant. We also see some positive and negative gains in various clusters. The difference between the overall pre-test scores in the

Traditional and *Learning-centered* courses is statistically significant.

TABLE 2. Comparison of various instructional styles. Statistically significant ($\alpha = 0.95$) changes within a particular style are in boldface.

	Learning-centered		Transitional		Traditional	
	Pre	Post	Pre	Post	Pre	Post
N	(107)		(47)		(101)	
Overall	60	60	57	61	53	48
Cluster						
Structure	52	55	41	51	43	39
Nature	56	53	54	58	51	49
Reality	77	75	71	77	64	58
Evolving	42	50	36	37	40	40
Source	72	68	74	68	64	54

Two courses were taught in more than one instructional setting. *A World of Light and Color* moved from a *Transitional* environment to *Learning-centered*, and one section of *Astronomy* was taught as a *Transitional* course, as opposed to the normal *Traditional* setting. Table 3 holds a synopsis of the post-test data for these courses. Clearly moving *Astronomy* from a *Traditional* to *Transitional* setting had positive impacts on student attitudes. Converting *Light and Color's* learning environment to completely pedagogically-inspired curricular materials seems to produce a mix of positive and negative effects.

TABLE 3. Post-test data for courses taught in more than one style. Statistically significant ($\alpha = 0.95$) changes within a particular course are in boldface.

	Astronomy		Light and Color	
	Trans.	Trad.	L-c	Trans.
N	(14)		(101)	
Overall	58	48	60	62
Cluster				
Structure	55	39	55	52
Nature	59	49	53	59
Reality	81	58	75	83
Evolving	39	40	50	30
Source	62	54	68	59

It is possible that the various instructional styles might affect students with initially weak attitudes differently than those with strong initial attitudes. To examine this, we divided the populations into two groups – *Experts* and *Novices*. For the entire matched set, roughly one-third of the students had pre-test scores at or below 53%. These students became our *Novices*. Likewise, roughly one-third of the students had pre-test scores at or above 64%. These students became our *Experts*. Table 4 shows the impacts the different instructional styles had on these two groups. (Note: The similarity of pre-test scores across each instructional style stems from our categorization.)

TABLE 4. Experts' versus Novices' overall scores for various instructional styles. Statistically significant ($\alpha = 0.95$) changes within a particular style are in boldface.

	Learning-centered		Transitional		Traditional	
	Pre	Post	Pre	Post	Pre	Post
Expert						
N	(45)		(15)		(20)	
Overall	70	64	72	73	72	60
Novice						
N	(30)		(19)		(57)	
Overall	47	55	44	51	45	40

Finally, we wanted to know if an instructional setting favored one gender over the other. Table 5 displays the results we found when we sorted the various instructional settings by gender. The differences in the overall scores between genders within a particular style are statistically insignificant. Again, the *Traditional* pre-test scores differ statistically from the *Learning-centered* courses.

TABLE 5. Comparison of males' and females' overall scores for various instructional styles. There are no statistically significant changes within any instructional style.

	Learning-centered		Transitional		Traditional	
	Pre	Post	Pre	Post	Pre	Post
Male						
N	(65)		(21)		(54)	
Overall	60	58	56	61	53	48
Female						
N	(42)		(26)		(46)	
Overall	61	62	58	62	53	47

DISCUSSION AND CONCLUSIONS

Overall, there was no appreciable gain in attitudes as determined by our instrument. Looking at the three instructional styles independently, we see no real improvement for the *Transitional* and *Learning-centered* courses, which, in light of published reports, is progress. The scores in *Traditional* classes slid back five points. In the end, students in the *Traditional* sections were about 12 points behind the other students. Even accounting for the initially depressed pre-test scores, the *Traditional* students still lagged considerably behind students in the more research-based curricula.

One positive outcome was that *Novices* fared quite well in the *Transitional* and *Learning-centered* courses. This is encouraging, because it suggests an instructional technique that could help the research-

based curricula benefit everyone. By carefully analyzing the clusters (or even specific items) where the *Experts* slipped, one gains insight into the kinds of epistemologically-oriented curricular materials to develop. Hopefully, these targeted materials would prevent the *Experts* from slipping in those clusters, while, perhaps, further bolstering the *Novices*' scores.

Interestingly, we found virtually no difference between males' and females' pre-test attitudes. Differences in gains or losses for males and females within a particular instructional style were not significant, either. Instructionally, though, the question remains open as to whether curricular materials that significantly improve students' epistemological attitudes need to be tailored to males and females, or whether a generic approach will suffice.

We only weakly controlled for the effect of a course's content on students' attitudinal gains. Nevertheless, courses that changed instructional styles followed the patterns we saw across the styles, which helps to establish that our results depend on instructional style and not content.

The *Traditional* students, all of whom were in *Astronomy*, pre-tested at a statistically significant lower level than the *Learning-centered* students. Perhaps this bias made the *Traditional* students less receptive to improving their attitudes about the nature of science and learning science. We did, however, demonstrate that the *Experts* in the *Traditional* sections decreased the most; moreover, *Novices* in *Transitional* and *Learning-centered* environments gained the most. So it seems unlikely that the low pre-test score of the *Traditional* students is indicative of their capacity or willingness to improve.

Unfortunately, we could not probe the influence of the professor on students' attitudes because of insufficient mixing of instructors across styles. In particular, none of the *Traditional* instructors taught in either of the research-based settings. The effect of the instructor on epistemological attitudes remains an open research avenue that needs to be explored.

All of this confirms that, for this group of students (just like the reports of physics students), improving students' attitudes about learning science and the nature of science does not come from curricular materials designed only to address conceptual understanding. Our *Learning-centered* course implicitly addresses issues related to several of the clusters by forcing students to postulate and learn for themselves (*Nature & Source*); focusing on fundamental concepts that explain a host of physical

phenomena (*Structure*); and having students experience simple, explainable, real-world phenomena in the classroom (*Reality*). Nevertheless, it fails to improve students' attitudes. In order to realize instructionally significant gains in epistemology, it seems we must carefully craft materials demanding students to overtly and critically evaluate how they learn science and the nature of science itself.

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