

What Factors Really Influence Shifts in Students' Attitudes and Expectations in an Introductory Physics Course?

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Abstract. To gauge the impact of instruction on students' general expectations about physics and their attitudes about problem solving, we administered two different, but related, survey instruments to students in the first semester of introductory, calculus-based physics at McDaniel College. The surveys we used were the Maryland Physics Expectation Survey (MPEX) and the Attitudes about Problem Solving Survey (APSS). We found that the McDaniel College students' overall responses were more "expert-like" post-instruction: on the MPEX, the students' *Overall* agree/disagree score started at 59/18 and ended at 63/17, and on the APSS, the students' agreement-score went from 63 to 79. (All scores are out of 100%.) All of the students to whom we administered the MPEX and a significant sub-group to whom we administered the APSS realized these improvements without experiencing any explicit instructional intervention in this course aimed toward improving attitudes and expectations. These results contrast much of the previously reported findings in this area.

INTRODUCTION

Students' attitudes and expectations about their own learning, a course's content, and the structure of scientific knowledge strongly influence how and what they will learn in a science class. Since the late 1990s, some physics education researchers have focused on characterizing students' attitudes and expectations, as well as developing curricular strategies and materials intended to help students realize more sophisticated attitudes and expectations. The article "Student Expectations in Introductory Physics" by Redish, Saul, and Steinberg helped catalyze this movement by showing that entire groups of students frequently averaged *lower* on the Maryland Physics Expectation Survey (MPEX) after one semester of introductory physics instruction, even in cases when the course in question had a strong research-based foundation.[1]

One oft-cited example of a course successfully designed to positively impact students' attitudes was reported by Elby in 2001.[2] In his Virginia high school physics class, Elby purposely exposed his students to materials that would help raise their awareness of their own thinking and the inherent organization of the library of physics knowledge.

Redish, too, reported gains on the MPEX after incorporating specific materials and approaches into an algebra-based course.[3] We also note that in Redish et al., one group of students' *Overall* MPEX scores resisted an erosion of attitudes. These students, under the tutelage of Pricilla Laws at Dickenson College, were exposed to *Workshop Physics*, which is a coherent and refined research-based curriculum.[4]

In 2002, we developed and administered (along with Stephanie Lockwood) a survey designed to probe students' attitudes about problem solving—Attitudes about Problem Solving Survey (APSS).[5] Some of the items of this 17-item survey were adopted from the MPEX, while others we included were unique to this instrument. The only set of pre/post-instructional data we gathered for reference 5 was for a group of students from Rensselaer Polytechnic Institute (RPI), and we found that those students experienced a negative shift in attitudes about solving physics problems. In light of the broader data published about the MPEX, this was not surprising. What was interesting and relevant for this paper was that McDaniel College students' post-instructional score was at a level that we felt was quite high (73% expert-like).

POPULATION, COURSE STRUCTURES, AND TIMELINE

This study involved students enrolled in *General Physics I* at McDaniel College in the Fall semesters of 2001 through 2005. This course is part of a calculus-based sequence and the only introductory physics course offered at McDaniel. (Details about McDaniel College can be found in reference 6.)

We collected demographic and background information in four semesters: 2001 (gender, only), 2002, 2004, and 2005. Nearly all students in this course are science majors. Over half are biology or biochemistry majors, many of whom are declared to be on the pre-medical-school track. Most of the students are sophomores, but all class years were well represented. The gender ratio was nearly one-to-one (M/F:49/51). Not surprisingly, the majority of students entered this course with significant previous exposure to formal science instruction. The average student for whom we have data ($N = 98$) self-reported over seven semesters of science in high school and over four semesters of science in college.

There were two phases to our study. In Phase I (Fall semesters 2001 and 2002) we collected matched MPEX data from one section of *General Physics I* at McDaniel College, which was taught by one of us, JM. We were interested to determine how these students' expectations changed over the duration of one semester of instruction, which was not specifically designed to influence attitudes. At that time, JM taught a "research-inspired" course focused on augmenting students' conceptual understanding of the material. Class time included Interactive Lecture Demonstrations and frequent in-class exercises designed to help students understand the basic physical concepts by applying them to simple exercises. The students' class grade depended on their scores on the homework problems (only three representative problems out of a particular set were graded); laboratory work; and in-class examinations that stressed, to varying degrees, mathematical solutions, as well as pictorial and verbal expressions of physical concepts. The research-based textbook was *Physics for Scientists and Engineers*, by Serway and Beichner.[7] As we mentioned previously, in the Fall of 2002 we also administered the APSS to McDaniel students, post-instruction only.

Phase II of our study began in the Fall of 2004. In this phase we included the other section of *General Physics I* in our study. That section was taught by Dr. Apollo Mian [AM], a professor interested in

incorporating research-based curricular materials into his class, but who is not a physics education researcher. Both course sections were very similar. JM and AM used the same research-based textbook (Cummings, et al., *Understanding Physics* [8]); covered essentially the same material at the same pace; used similar, and in many cases, exactly the same, research-inspired curricular materials in lecture, as describe above for Phase I; assigned the same homework problems and posted the same solutions to our respective websites; and shared a common set of laboratory sections. The basis for students' grades in both sections was similar to Phase I. However, there were differences between the two sections that are relevant for this paper.

Bolstered by the high post-instructional average from 2002, and with hopes of realizing even more sophisticated post-instructional attitudes, JM augmented his class instruction by devoting time to modeling, and helping students model, effective problem solving. This included having students learn to draw an effective sketch of the problem (later in the course referred to as a "non-mathematical representation" [9]); record knowns and unknowns; identify assumptions; explain the major physical principles, which would serve as the starting point for the solution; and list all of the relevant "starting" equations (which came from a short equation sheet that JM provided at the beginning of the term).[10] To help reinforce this tactic for solving problems, JM graded three problems from each homework set for the correct mathematical solution, but also for how well students applied this approach, which accounted for one-third of a student's homework grade. Also, formal exams had at least one problem in which points (10% of the exam grade) could be earned only by applying "good problem-solving techniques." AM did no such modeling or reinforcement, and grades he awarded on homeworks and exams were solely based on a student's mathematical solutions. We refer to JM's sections as Problem-Solving (*PS*) intensive ($N = 33$), and AM's sections as Non-Problem-Solving (*N-PS*) intensive ($N = 28$).

ANALYSIS

Figure 1a below displays the MPEX data from Phase I arranged on an agree/disagree plot.[1] This highlights how a class' responses to the various clusters on the survey, as well as their *Overall* score, changed from pre-instruction to post-instruction. Figure 1b places the McDaniel College *Overall* score within the larger context of some of the published pre/post-instructional data for the MPEX.

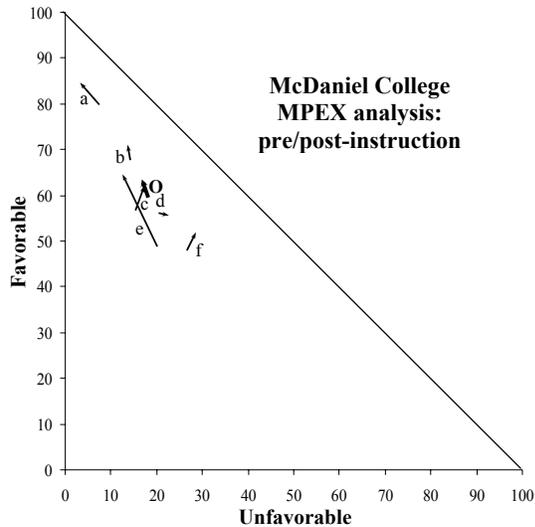


Figure 1a: McDaniel College students' expectations as measured by the MPEX. The arrows indicate the shift in score from pre-instruction (tail of arrow) to post-instruction (head of arrow). Individual thin arrows represent the various MPEX clusters: *a* - Reality, *b* - Effort, *c* - Math, *d* - Concepts, *e* - Coherence, *f* - Independence. The thicker arrow, *O*, represents the Overall score.

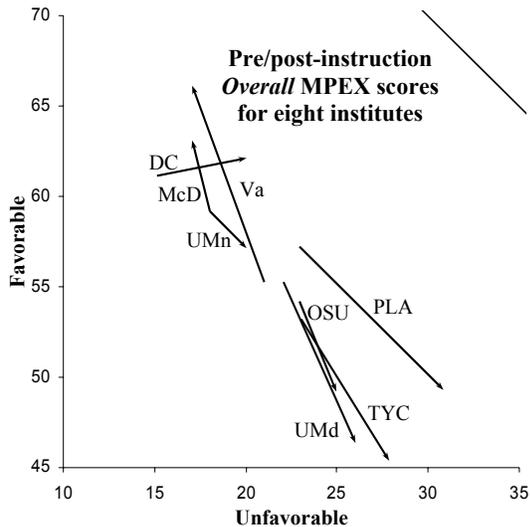


Figure 1b: Shifts in Overall MPEX scores for a variety of institutes, including McDaniel (McD). All of the data except McD and Va are adapted from reference 1. The Va data are adapted from reference 2. Notice that the scale of the agree/disagree plot has been increased 4× for legibility.

Figure 2 displays the matched pre/post-instructional scores on the APSS for two sections of McDaniel students during Phase II of our study (labeled *PS* and *N-PS*). Also included are the pre/post-instructional averages from RPI, and the post-instructional averages for McDaniel College

and Southern Connecticut State University (SCSU) for the Fall semester of 2002.

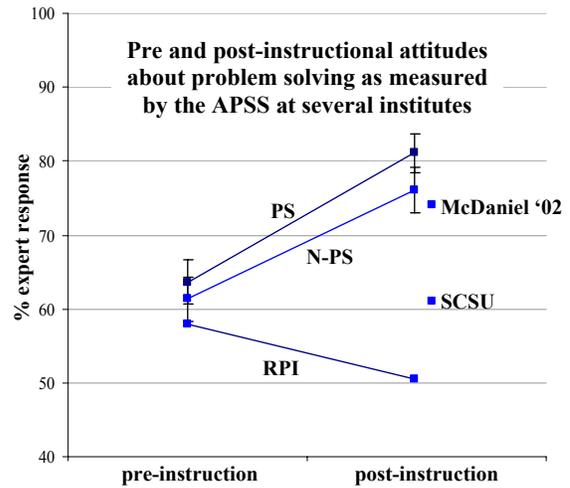


Figure 2: Pre/post-instructional data for the APSS. Error bars are the standard error. The points for which we have only post-instructional data are shifted slightly to the right for clarity purposes, only. The RPI data, and the post-instructional-only data for McDaniel and SCSU are adapted from reference 5.

DISCUSSION AND CONCLUSIONS

Our analysis revealed several interesting features. On the MPEX, the McDaniel College students avoided the typical negative shift in expectations from pre-instruction to post-instruction one might associate with a class not designed to address such issues. Furthermore, unlike the Rensselaer students who showed a negative change in attitudes about problem solving, the McDaniel students experienced a significantly positive shift, and much of this was realized without any instruction designed to motivate such change. It is worth noting that the datum point in Figure 2 representing the McDaniel College students' post-instructional score in 2002 was after instruction by JM, who, at the time, used an instructional strategy more like the *N-PS* style than the *PS* style. (The SCSU students lie at the middle of the post-instructional results; however, we hesitate to draw any conclusions about their pre-instructional attitudes, since they are a less traditional group of students than either the RPI or McDaniel cohorts.)

So, returning to the title of this paper we wonder: "What factors really influence shifts in students' attitudes and expectations in an introductory physics course?" Unfortunately, at this point we lack sufficient data to identify a mechanism or complex of mechanisms responsible for the overall positive

shifts in attitudes for the McDaniel students we have reported here. Lacking such insight, we find it difficult to confidently draw any strong conclusions; but, in a moment we will propose two hypotheses stemming from our analysis. For now, we can say that our results stand apart from much of the previously reported, peer-reviewed work. So, one can not presume *a priori* that students' attitudes will necessarily decay in a course that fails to explicitly address attitudes and expectations.

Our first hypothesis is that sophisticated pre-instructional attitudes, as measured by the MPEX, may inoculate students against the deleterious effects of a non-attitudinally-oriented course. Ignoring the exceptional Virginia MPEX data, which was the result of a carefully planned intervention, the three institutes with the highest pre-instructional scores—Dickenson (DC), McDaniel, and the University of Minnesota (UMn)—all saw the smallest negative shifts, and in some cases, positive shifts. Anecdotally, other unreviewed data we have seen supports our proposition. Additionally, it seems inoculation may be more complete for some areas than others. For example, the McDaniel students' *Concepts* score did not present a particularly favorable shift. Regarding attitudes about problem solving, high pre-instructional attitudes may only weakly influence gains in that area. Unfortunately, our APSS data does not strongly compliment our hypothesis. The pre-instructional data for RPI seems barely distinguishable from the McDaniel data. Lacking MPEX data for RPI prevents us from broadening or rejecting our hypothesis.

Our second hypothesis is that the two groups of students who most resisted MPEX-measured degradation—McDaniel and Dickenson—were self-selecting for and/or acculturated in similar academic environments. Both institutes are small, private, nationally competitive, liberal arts colleges in bordering states with modestly-sized physics departments. Furthermore, both colleges have at least one full-time faculty member who is a physics education researcher devoted to teaching introductory physics. We posit this combination of traits may attract a particular kind of student and then implicitly reinforce the importance of achieving attitudinal gains. Reference 1 also includes information about an un-named, *public* liberal arts college (PLA). Unfortunately, because we know so little about this population and the sample was so small ($N = 12$), we hesitate to reject our hypothesis based on that group. Because of a shortage of data, it is difficult to determine if our APSS results compliment our second hypothesis.

Before concluding, we shall discuss observations regarding the McDaniel APSS results. Although a considerable fraction of the attitudinal gains seems to have occurred “naturally,” the *PS* instructional approach produced a measurable effect on this population. We hope these results will help motivate introductory physics instructors interested in augmenting their students' attitudes about problem solving to consider implementing similar methodologies. We feel our approach would have a similarly positive influence on students who would normally achieve no, or small, positive attitudinal gains with respect to solving physics problems.

To conclude, our McDaniel APSS pre/post-instructional data further demonstrates that courses openly designed to influence students' expectations and attitudes are worth developing and can have demonstrable results. However, we have also uncovered that instructional environments that fail to explicitly address students' attitudes and expectation do not necessarily doom students to the negative shifts that we and others have previously reported in the literature. Finally, more research is clearly required to support or reject either of our hypotheses regarding factors that influence shifts in attitudes.

ACKNOWLEDGMENTS

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