Curriculum design for the algebra-based course: Just change the 'd's to deltas?

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Abstract: The PIs have been involved in an NSF-funded project to develop materials for the introductory mechanics laboratory. The materials are based on the instructional approach taken in *Tutorials in Introductory Physics* (curriculum developed in the context of the calculus-based course at the University of Washington) [1]. While the materials being developed are intended for the algebra-based course, at many universities the labs are common to the two courses. As a result, we have been looking at differences in performance between these two student populations. In this poster, we describe the differences we have observed, especially as related to graphs, proportional reasoning, and algebra. It turns out that you *cannot* just change the d's to Deltas—who knew? We will discuss implications for instructors and for curriculum developers.

Keywords: Labs, Physics, Algebra-based, Population Differences, Student Understanding.
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INTRODUCTION

Most universities offer both a calculus-based introductory course that uses derivatives and integrals as part of physics instruction and an algebra-based introductory course that does not. Students in the calculus-based course are typically engineering and physical science majors. While it is often assumed that the algebra-based course (sometimes known as trig-based physics or college physics) is intended for life sciences majors, the student population for this course varies significantly from one university to another. For example, at New Mexico State University (NMSU) about one-third of the students in this course are engineering technology majors and 10% are agriculture majors.

Most of the research and curriculum development in physics has been in the context of the calculus-based introductory course. Furthermore the primary testing of this curriculum has been at large research universities. If some aspect of a physics topic proves to be challenging to students in a calculus-based course, the same difficulties are likely to be found among other students. However, there may be additional challenges to learning in other populations. Thus while curriculum that has been designed for students who are primarily engineering majors may be helpful for other students, there may be additional considerations that must be taken into account when designing curriculum for other student populations. In this paper we describe our initial attempts to characterize some of these additional considerations for students in the algebra-based course.

DESCRIPTION OF RESEARCH

The authors are PIs in an NSF-supported project to develop research-based laboratories for the introductory mechanics course. The labs we are developing focus on evidence-based reasoning and on concept development. We intended to develop labs appropriate for both algebra-based and calculus-based sequences, since many universities use the same labs for each. The research base upon which we intended to build primarily included studies of students in the calculus-based course, so we wanted to investigate whether there were identifiable contexts for which these populations were measurably different. More generally, we would like to begin to explore the degree to which population differences from course to course and from one university to another affect attempts to implement research-based materials.

Context for Research

This study was performed in the context of algebra-based and calculus-based introductory physics lab courses at two universities, California State University Fullerton (CSUF), and New Mexico State University (NMSU), both comprehensive state land grant universities serving diverse student populations. CSUF, the second-largest university in California, serves over 37,000 students and is among the top institutions nationwide in terms of degrees awarded to minority groups. New Mexico State University has an enrollment of 16,000 students and has a minority enrollment of 53%.

Both universities have two introductory physics sequences, one algebra-based (two semesters), and one calculus-based (three semesters, although many majors only require the first two semesters). We abbreviate the former ABM (algebra-based mechanics), and the latter, CBM (calculus-based mechanics). In both cases, the first semester of the sequence focuses on mechanics, though ABM typically also includes 2-3 weeks of thermal physics and/or fluids. Both sequences have three hours of lecture each week, with no small-group recitation sections. Each sequence has an associated three-hour lab. At CSUF the lab is required for both courses. At NMSU, the labs are required for some majors but not for others. For the most part, the lectures for both courses at both institutions are traditionally taught, though individual lecture instructors have used research-based curricula.

Methods

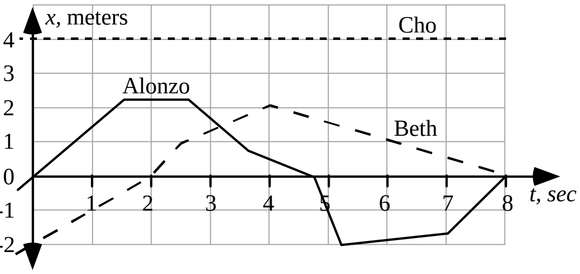
All data in this paper were collected by analysis of student responses to free-response or multiple-choice written questions posed on course and laboratory pretests, examinations, and quizzes (both graded and ungraded). The questions were constructed based on examination of the research literature as well as on previous work by the authors. In most cases students were asked to provide an explanation, often including a drawing, in addition to their answer. Student research assistants performed data entry and analysis with consultation by the study authors.

In the four sections that follow, we describe areas where we noticed differences in response patterns between ABM and CBM students.

TASKS AND RESULTS

Kinematics graphs

We have observed differences between populations in response to questions about one-dimensional kinematics. An example of these differences is in student responses to the questions associated with the diagram shown in Fig. 1. These questions were asked on a multiple-choice laboratory final.



Alonzo, Beth, and Cho are in a hallway. Shown is a graph of their positions along the hallway as a function of time.
Q1: At time zero, which people have positive velocities?
Q2: What is Beth's velocity at time t = 6 seconds?

FIGURE 1. Questions requiring interpretation of kinematics graphs.

For Question 1, about 61% of 66 CBM students at NMSU recognized that Alonzo and Beth had velocities greater than zero at time zero. Only 27% of 66 ABM students answered correctly. On Question 2, about 68% of the CBM students and 38% of the ABM students correctly answered that Beth's velocity at six seconds was –0.5 m/s. A popular distractor for this question is –0.167 m/s, an answer consistent with dividing the position at t =6 s (1 m) by 6 s. This response (or +0.167 m/s) was chosen by about 20% of the CBM students and by 29% of the ABM students.

Based on the difficulties we had observed in the context of kinematics graphs, we decided to probe student understanding of the concept of slope in the absence of any physics context. Results for these questions are shown in the following section.

Slope Problems

We posed a series of questions on the concept of slope on an ungraded pretest before the beginning of a series of labs on graphs and kinematics. Two sample questions are shown in Fig. 2.

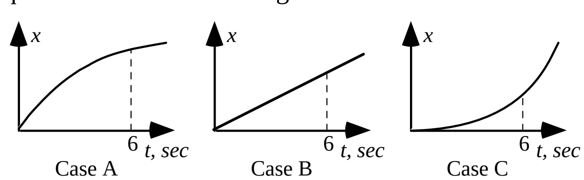


FIGURE 2. Graphs for slope comparison questions.

Students' responses are summarized briefly in Table 1. The table shows the percent of correct responses in the two courses at CSUF for various tasks involving slope. Some questions proved to be quite simple for both classes, or equally difficult for both classes. On several other questions, however, there were significant differences in the performance of the two populations.

Task	ABM (*N = 83)*	CBM (*N = 68)*
Identify constant slope	92%	95%
Identify increasing slope	67%	93%
Compare slopes	41%	48%
Sketch decreasing positive slope	48%	70%
Sketch constant negative slope	72%	88%
Compute slope of line with m < 0	34%	62%
Compare slopes on a straight line	73%	83%
Identify sign of slope on curve	49%	> 74%

TABLE 1. Comparison of responses on slope questions for ABM and CBM at CSUF (percent correct given).

Generally, the questions for which the results were similar were those involving slopes of of straight lines. (A notable exception is a question requiring students to compute the slope of a straight line with negative slope; about a third of the students in ABM answered correctly as compared to about two thirds in CBM.)

Problems that required the interpretation of the slope of a curved graph tended to show significant differences between the two populations. For example, students were asked to choose which of the graphs in Fig. 2 had a 'slope that is increasing with time.' While almost all of the students in the calculus-based course answered correctly, about a third of the students in the algebra-based course did not.

Reasoning about ratio and proportion

We have observed differences between CBM physics students and ABM physics students for questions requiring an interpretation of a ratio or of a proportion. For example, the question shown in Fig. 3 was asked of ABM and CBM students as a multiple-choice pretest question on the first day of lab at NMSU. (This question was modeled after a similar question about charge density [2].) About 65% of 141 CBM students and 45% of 165 ABM students answered correctly that the densities were all the same.

A uniform block of cheese is cut into two unequal pieces, labeled A and B. The *mass density* of an object is defined as the mass of that object divided by its volume. Rank the mass densities of the original block, the largest piece (A), and the smallest piece (B).

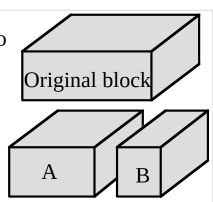


FIGURE 3. The broken block question.

With slight variations, the broken block question has also been asked as part of a pretest in a CBM course at the University of Washington and a conceptual physics class for non-science majors at Northwestern Louisiana State University [3]. Results differ dramatically, as shown in Fig. 4. It is interesting to note that when the question was asked at NWLSU without the definition for mass density included, scores actually slightly *improved.*

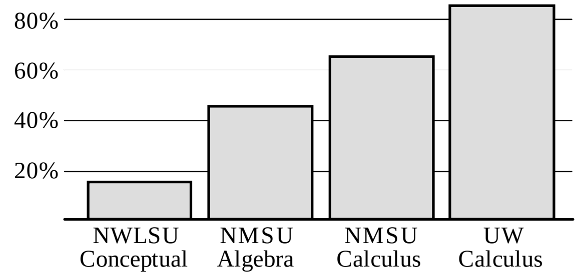


FIGURE 4. Performance on broken block question for different populations.

There are 4 questions about proportions on the Lawson Classroom Test of Scientific Reasoning [4]. At NMSU we have added the broken block question shown in Fig. 3 to these four questions to form a ratio and proportion pretest. About half of the CBM students answer four or five of the five questions correctly, while about half of the ABM students score either a zero or a one on this pretest. The distribution of scores is shown in Fig. 5.

As others have found [5], there seems to be a correlation between students' pretest scores on these kinds of questions and their scores on post-tests used to measure conceptual understanding at the end of a mechanics course. In our case, we found a correlation of about 0.55 between student scores on this 5-question pretest and their performance on a 30-question multiple-choice lab final intended to measure understanding of concepts underlying the labs.

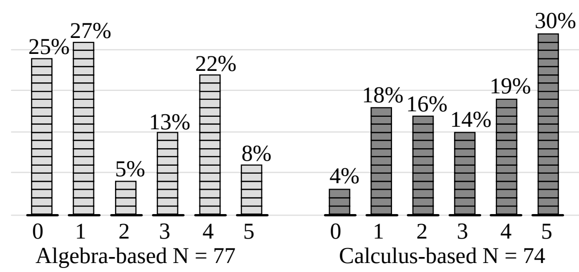


FIGURE 5. Distribution of pretest scores for questions about ratio and proportion.

Whether questions of this type are actually measuring student *ability* is, we believe, an open question. We are conducting experiments to explore whether students are more successful with questions that have the same content in terms of ratio and proportion as these, but that are less formally posed.

Tension

Another context in which we have observed differences between populations is that of tension. We have developed and tested a lab about the vector addition of forces using a force table. Our preliminary work in this development suggested that many students had difficulty in understanding the effect of pulleys on tension, a result also reported by by McDermott et al. [6]. We posed a variety of questions that probed students' understanding of tension along a single string and along multiple strings. For the massless string in the question shown in Fig. 6(a) the tension is the same at all labeled points. About 37% of the 46 students in the ABM course answered correctly, compared to about 19% of the 43 students in CBM at CSUF – a rare case where students in ABM actually outperformed those in CBM..

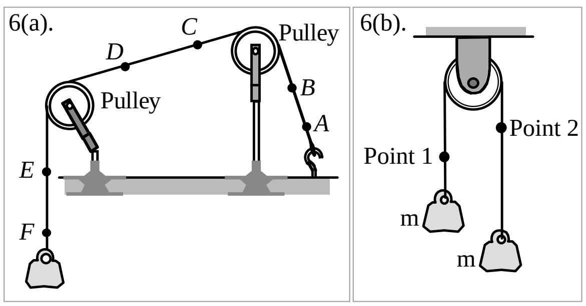


FIGURE 6. Students are asked to rank (Fig 6(a)) or compare (Fig. 6(b)) tensions along a massless string. For both questions tensions are equal at the labeled points.

On the same ungraded pretest, a different tension problem (Fig. 6(b)) was more difficult for the students in the algebra-based courses (54% correct in ABM vs. 77% correct in CBM). The incorrect answer that the tension at point 2 was greater than the tension at point 1 was much more prevalent in the algebra-based course (26% in ABM vs. only 5% in CBM).

DISCUSSION AND CONCLUSIONS

On many of the questions that we have posed, the fraction of students obtaining a correct response is different in the algebra-based course than it is in the calculus-based course. Moreover, the *pattern* of incorrect responses is often different, with some incorrect responses being more prevalent in one course or the other. There were other questions for which we observed no significant difference between responses from these two student populations, and even cases in which the students in the algebra-based course outperformed those in the calculus-based course.

There were some topics for which our results suggest that students in ABM, whereas it would have relatively little effect CBM students as a whole. For example, our results suggest that students in the ABM course may need additional help in considering the meaning of the slope of curved graphs.

The details of our results suggest that the differences between the two populations are not simple, and that it is not valid to assume that instructional approaches that work with one population can be imported without modification for the other.

We believe that the physics education research community has in general paid insufficient attention to differences in student populations. As a lowest order approximation, the approach that "If it worked with group *A* it will work with group *B*" has served us well in terms of dissemination of research-based curricula. However, we have seen examples of content for which implementation of research-based curricula has not yielded the same benefits for our students as we might have expected based on results obtained at the institution where these materials were tested.

There are a large number of variables that we are unable to control for or even completely document, including the differences in lecture instruction, the timing and emphasis of lecture topics, and even the guidance given to students by individual lab instructors. While we have focused here on the differences between ABM and CBM courses, we see in our data some signs that there might be differences between students at the two universities. Moreover, it seems reasonable to us to assume that we can expect to see variation based on factors such as school selectivity, culture, student age, and other possible variations. We believe that learning more about population-based variations in student responses will allow us to better tailor instruction.

ACKNOWLEDGMENTS

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REFERENCES

1. McDermott, L.C., et al., *Tutorials in Introductory Physics,* Upper Saddle River, NJ: Prentice Hall (2002).
2. Stephen Kanim, "An investigation of student difficulties in qualitative and quantitative problem solving: Examples from electric circuits and electrostatics," Ph.D. thesis, University of Washington, 1999
3. G. White, "Pre-Instruction State of Nonscience Majors - Aspects of Density and Motion," *AAPT Announcer* **30**, Winter 2000.
4. A. E. Lawson, "The development and validation of a classroom test of formal reasoning," J. Res. Sci. Teach. 15(1), 11–24 (1978).
5. V.P. Coletta and J.A. Phillips, "Interpreting FCI scores: Normalized gain, preinstruction scores, and scientific reasoning ability," *AJP* **73** (12), 1172-1182, (2005).
6. McDermott, L.C., P.S. Shaffer, and M. Somers, Am J. Phys 62, 46-55 (1994).