

Improving Learning for Underrepresented Groups in Physics for Engineering Majors

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Abstract. The Extended Analytical Physics course at Rutgers University was crafted to improve learning in the first-year physics course for students mathematically under-prepared for engineering physics. It is a core course in the engineering curriculum and has contributed to the increase in success of underrepresented groups in physics and in subsequently in STEM majors. This article describes the evolution of this course, its current structure, the successes measured and the future plans.

Keywords: underrepresented minorities, gender, retention, engineering, STEM

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INTRODUCTION

Rutgers, The State University of New Jersey, is an urban, highly diverse research university. Since 1986, its department of Physics and Astronomy has significantly improved the learning experience and retention of at-risk students in engineering [1,2] by offering Extended Analytical Physics.

Many current publications [3,4,5,6] examine the inequitable representation of women and underrepresented minorities (URM) among the science, technology, engineering and mathematics (STEM) degree recipients. Concerning access to higher education, recommendation #1 of the Congressional Commission of the Advancement of Women and Minorities in Science, Engineering, and Technology Development⁴ includes “... *aggressive, focused intervention efforts targeting women, underrepresented minority and disabled students ...at the transition to post-secondary education...*” The objectives of the Extended Physics program reflect that recommendation, as we see physics as a major barrier to many students contemplating careers in STEM. Specifically, we try to:

- 1) Improve the quality of learning in the introductory analytical physics course.
- 2) Provide a learning environment to which all students feel they belong, regardless of gender, ethnicity or any other distinction.
- 3) Improve the retention rates of women and URM in STEM majors.

- 4) Establish mentoring relationships between the students and the Extended Physics team members.

BACKGROUND

In 1987 the Rutgers University administration offered new special funding on a competitive basis with the goal of increasing student retention and satisfaction among first-year students from groups underrepresented in STEM disciplines. The Department of Physics and Astronomy was awarded funding and TA lines to experiment with reforms in the introductory physics course for engineering majors.

The first version [2] of the reform was the creation of a one-semester pre-physics course designed to remedy the inadequate mathematics preparation that characterizes most at-risk students. The course was meant to act as a bridge between high school and introductory college physics courses. Although there was a need for the course, after just three semesters the pre-physics model was abandoned for three main reasons: 1) the students felt stigmatized, 2) the students were obliged to spend an additional year, since the mainstream physics sequence starts in the fall, and 3) one semester was too short for preparing the students for the traditionally-taught first-year mainstream course, Analytical Physics I (AP I). In retrospect, stereotype threat [7] probably contributed to the stigma and subsequent failure of this model.

Stereotype threat is jeopardizing success at a task by telling students up front that people from their group typically do poorly on the task at hand.

In 1989 the one-semester pre-physics course was replaced by a two-semester Extended Analytical Physics course (EAP I) that became an alternative path from the traditionally taught two-semester AP I– the mainstream course for engineering majors (see Fig. 1)

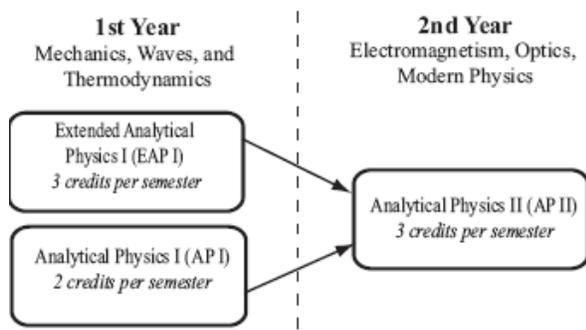


FIGURE 1. Introductory physics courses offered to engineering majors.

The parallel two-semester course structure in the first year of physics resolved the problems encountered in the pre-physics model. The current structure offers an alternative to the traditionally taught first-year course, in place of a preparatory course. Under this structure there was an opportunity to target underrepresented populations in the first year without isolating them. EAP I is dominated neither by women nor by URMs, but the course provides a culture of learning in which these students excel along with their peers. The parallel (and more evenly populated) structure represented an important innovation that led to an improvement in the learning experience of students from groups underrepresented in STEM [1,2,8].

PEDAGOGICAL FEATURES

Current Course Structure

Student placement in EAP I is based on low math placement test scores (concurrent placement in pre-calculus). Approximately 30% of the EAP I students each year are in Educational Opportunity Fund (EOF) program, the majority of whom are African American and Latino(a). EOF provides financial and other support services to first-generation, economically disadvantaged students. There is a higher percentage of female (~25% each year) and URM (~20% each year) students in EAP I than in AP I (~20% female and <10% URM).

Structurally, one can compare EAP I to AP I in a variety of ways. Each week the students meet twice

for recitation and twice for lecture in EAP I, thus spending twice as much time in class as the AP I students do. There is no required lab in the first year for either course. Recitations are run by graduate teaching assistants in both courses, and are limited to an enrollment of 20 students in EAP I. The total enrollment in EAP I ranges between 120-180 students each year, while the AP I enrollment ranges between 250-400 students. A rough rule of thumb to compare the structures of EAP I to AP I is half as many students in lecture and in recitation and twice as much contact time.

Role of Course Staff

The role of the course staff in EAP I cannot be overemphasized [1,8]. The Lecturer/Course Coordinator and the instructors develop very close relationships with the students because all of the learning activities are interactive. In one study¹ it was found that one of the aspects of the course that all of the female students felt contributed to developing their confidence in doing physics was that the lecturer knew them by name and cared about their individual performance. Many of the students stay in contact with the EAP I staff throughout their careers at the university, and some even after that. The EAP I staff help provide encouraging role models and a support system that is an important part of success for female and URM students [9,10]. Our students report [1] that they leave this course much more confident about approaching their professors and other professional adults. Approaching professors is how mentoring is born in college, so students are being prepared for developing future important collaborations.

Curriculum and Assessment

At the outset, we were convinced that developing mathematical reasoning skills was necessary to compensate for the weak mathematical abilities as measured by the Math Placement Test at Rutgers. EAP I is a calculus-based course and the students don't start calculus until their second semester. The students could perform most necessary procedures perfectly well but they were very poor at deciding when to use math, and what math to use. We have developed reasoning-building activities that are integrated into the physics curriculum.

In addition to problem solving mastery, another important component to developing an inclusive scientific community is developing scientific abilities. The Investigative Science Learning Environment (ISLE) [11] curriculum got its Rutgers' start in EAP I in 2001. ISLE provides a setting for students to use

the processes of science and cognitive strategies that help them construct physics and mathematics ideas. They learn to apply these processes to real-world problems. We have refined and adapted features of ISLE in the context of this course. The current curriculum is a hybrid of ISLE infused with mathematical reasoning skill-developing activities.

In addition to weekly homework, students are assessed twice each week in recitation, once through oral examination and the other through a written quiz. They take two midterm exams and a final which are comprised of multiple choice problems typical of most introductory engineering physics courses, open-ended problems that require use of multiple representations and reasoning in addition to mathematics, and an experiment problem that requires synthesis of written skills, mathematical reasoning and experimental problem solving.

An important feature of EAP I is the students' involvement in activities that prepare them for their professional lives as practicing engineers [12]. Specifically they design experiments in a group of 2-3 over the course of the semester. They use the Scientific Abilities Rubrics [13] to self-assess as they prepare their papers and presentations during the semester. They prepare a five minute peer-reviewed talk on their research (including data and analysis) and an accompanying paper. They start learning to conduct themselves socially and academically like practicing engineers and scientists [12].

RESULTS

Assessing the success of an entire program is a challenge. It is necessary to measure from a variety of perspectives in order to get an image of success and failure. In one perspective, our students have gains on the FCI consistent with gains in other interactive engagement courses [14]. But this type of measure doesn't tell us whether or not we are meeting most of our goals.

Another perspective is to determine whether or not the students are able to perform comparably to mainstream students by traditional standards. In 1995 and 1996, we gave common final exams at the end of the year in AP I and EAP I. In both years there was no statistically significant difference in the final exam average between AP I, EAP I or for the subgroups of female or URM students. From this we conclude that EAP I students close the physics gap by the end of their first year of physics under our program, as measured by a traditional final exam.

To get another perspective, we look at the demographics of who succeeds in freshman physics (see Table 1). We see that there is a significant improvement since the course was introduced, even

though the average SAT math scores haven't changed. We average over two years preceding the intervention, looking at all students in two years from both courses ($n_A=1,130$), the female subset ($n_f=203$), and the URM subset ($n_{min}=152$). Then we do the same after the introduction EAP I ($n_A=968$, $n_f=194$, $n_{min}=128$) and finally for the most recent two years of instruction ($n_A=820$, $n_f=159$, $n_{min}=116$).

TABLE 1. Passing rate of first-year physics, AP I and EAP I combined.

	All	Women	Underrep. Minorities
Before (‘85&‘86)	64% ± 1%	55% ± 2%	28% ± 3%
After (‘92&‘93)	76% ± 2%	76% ± 3%	59% ± 3%
Current (‘07&‘08)	73% ± 1%	71% ± 1%	69% ± 1%

For a longitudinal perspective we look at the improvement in retention in STEM majors (see Table 2). We see that STEM degree completion for underrepresented groups has improved markedly since the course was introduced. We look at the students who have completed one year of physics, and check to see what percentage of those students obtain a STEM degree from Rutgers within six years.

TABLE 2. Completion of STEM degree at Rutgers University within six years.

	All	Women	Underrep. Minorities
Before (‘85&‘86)	45% ± 3%	32% ± 4%	8% ± 4%
After (‘92&‘93)	57% ± 3%	59% ± 4%	53% ± 4%
Current (‘07&‘08)	68% ± 2%	70% ± 3%	58% ± 3%

We don't take credit for the marked increase in degree completion, but feel fairly confident based on feedback from the Deans of Engineering and EOF that we have played an important role in contributing to that success. The other core courses in engineering that students take in their first two years are traditionally taught, ours is the only course that is taught much differently than it was 20 years ago. The profile of the students hasn't changed much in terms of SAT scores. There are, though, a wider variety of STEM majors than there were 20 years ago with a steep rise in options in computer-related fields. We don't know what effect, if any, this broadening of options has had on the retention of engineering students in STEM majors. A more certain positive effect is the contribution made by the other support programs that the EOF students are involved in through their EOF program in engineering. But there

has been no marked change in the EOF program that correlates temporally to the improvements we measure. Certainly, we are a part of a partnership whose goals overlap, and each partner is contributing to meet these goals.

The importance of community inclusion to the success of underrepresented groups in STEM is becoming more evident. In the language of social cognitive theory forwarded by Bandura [15], the vicarious experiences (observing peers succeed) and social persuasions (genuine positive reinforcement) experienced in a scientific community contribute to developing self-efficacy, or one's belief in one's own ability to achieve a particular "task" – like excelling in a physics course. In one study of first year engineering students [9], women reported more frequently than men the positive effect of working closely with team members. In another study of professionals in math-related careers [16], women were found to be more frequently influenced by vicarious experiences such as group membership and sincere encouragement from community members. Similar findings are reported in one study of African American physics majors and graduate students [10].

Future research should include trying to understand: What role self-efficacy plays in students' success in EAP I, and which activities are best at developing it? Is it possible to create successful communities in the context of physics courses typically found in a large research university? How do we measure the point at which a student functions productively in a physics community? The answers will help us to better pinpoint more precisely which features of EAP I are worthy of replication in other institutions, and which features might be considered essential to any physics course.

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