Improving Physics Education—How And Why

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Introduction

In 1990, President George Bush and all 50 governors announced their goal for U.S. students to be first in the world in mathematics and science achievement by the year 2000. It was an ambitious goal, but as many are probably aware, we did not even come close to reaching it. Compared to their peers abroad, twelfth-graders still rank near the bottom in math and science achievement, a conclusion of a comprehensive international comparison entitled *The Third International Mathematics and Science Study* (U.S. Dept. of Ed., 1998). The study involved over 41 nations and more than one-half million students. Part of the study included testing the higher achieving students from 16 nations in advanced mathematics and advanced physics. The results for American students were dismal, again. The United States placed 15th out of the 16 nations in mathematics and last, 16th out of 16, in physics. If the Asian countries had chosen to participate, the results would probably have been even worse. These poor results occur even though the United States spends more dollars per student on education than any other industrialized nation of the world (*USA Today*).

The implications these results have for the United States are grave and should be of concern to all people both in and out of education. In this paper, I will discuss the important role two-year college faculty have in dealing with low student achievement in math and science and suggest actions that can be taken to improve students' understanding of physics and mathematics. Although my primary interest is physics education, physics and mathematics are closely linked, and it is very difficult to be successful in physics without being competent in mathematics. Therefore, the discussion of improving a student's understanding of mathematics is included.

Post Secondary Physics Education

Not only are there problems at the secondary level with math and physics education, but there are also problems at the college level. Many of the students represented in the above results end up attending regional and two–year college campuses. They become our students. Their achievement at the college level is frequently inadequate, and we, as professors, are partially to blame because of the way we teach. Recently, I overheard a conversation between two non–physics faculty from an Ohio university. One of them stated that at their campus, a student in a physics course had an average of 8% and got a D as a final grade. The highest average in the course was a 68%, and that student got an A. The other faculty member astutely observed, "Something is wrong there." I would have to agree.

The problem is compounded by the way physics is sometimes taught. The students are turned off. At a workshop I attended, a professor from an Indiana university shared with us the conclusion that in a survey done at his campus the most disliked course on the campus was a physics course. Physics courses at many schools are used to weed out students planning to enroll in engineering, pharmacy, or other professional schools. The goal of a physics course should be for the students to learn physics, not to weed out students. One way students respond to the weeding out process is to change majors to avoid taking physics. Physics enrollments have been declining at the post secondary level. The weeding out process seems to be working. Unfortunately, it is at a time when there is a need to increase our understanding of our physical world. The integrity of a course can be maintained with high expectations without losing a large number of students in the process. Two–year college faculty have a role to play at both the secondary level and the college level in helping students to learn and to succeed.

Suggestions For Improvement

1. Promote the importance of math and physics education. As some have said, "Physics is the liberal arts education of the 21st century." What is physics? Why is it important? These are good questions, but the answers are not as obvious as people might think. Answers to these questions must be communicated to students, parents, other teachers, and the general public. At its simplest, physics is the study of our physical world and the laws that govern it.

More and more, our society depends on technology. Technology is ruled by the realities of physics. We need people with an understanding of the laws governing our physical world to manage and maintain our technology. Companies that compete in the global economy need employees with technical skills in order to remain competitive, yet companies report that many employees lack the most basic technical skills. Having students who consistently remain at the bottom of science and math achievement internationally will eventually result in a lower standard of living in this country. We will not maintain our standard of living by adding more service jobs at the local shopping mall.

Physics is important to people in other jobs as well because physics principles are used every day. An understanding of the physical laws governing our world would help business managers and politicians make better decisions and reduce workplace accidents and injuries.

Studies have found that elementary and junior high teachers express the greatest anxiety over their preparation for teaching science, especially physics. It is not hard to imagine that students entering high school have sensed their past teacher's anxiety and formed the opinion that physics is hard and only for science–oriented or college–bound students.

As two–year college faculty, we can look for opportunities to communicate the importance of physics education to students and the general public through papers, newsletters, conversations, talks to local community groups, and so on.

2. Raise the standard. U.S. Secretary of Education Richard W. Riley stated in a press release in 1998 that ". . . academic standards must be raised dramatically across America . . . . Far too few high school seniors have taken physics, trigonometry, calculus, and advanced placement courses" (NCES Press Release). Studies have shown that over half of the math courses offered at two–year colleges are remedial courses, primarily basic arithmetic and elementary and intermediate high school algebra (Loftsgaarden, 1997). It is no surprise that the problem most frequently cited by physics teachers at two–year colleges has been the weak mathematics backgrounds of students (American Institute of Physics, 1998). The low standards of our educational system in the U.S. are negatively affecting our ability to compete internationally. *Developing Technicians–Successful International Programs* indicates that for U.S. companies to maintain a competitiveness in the global market place our technicians "must display at least the same level of skill and competency as their counterparts in other countries." The low standards of our educational system are costing us millions of dollars to offer the same courses twice—once in high school and again in college. As we work on program and curriculum development, we should include rigorous math and science standards and encourage other people, at all levels of education, to do the same. We need to promote the message that it is not OK to be dumb in math and science.

3. **Spend more time on the subject areas.** This notion is similar to the suggestion above but is important enough to list as a separate item. When the number of days spent in the classroom per year among industrialized nations is compared, the U.S. ranks as one of the lowest (*U.S. News and World Report*). One of the concerns listed in *Developing Technicians—Successful International Programs* is that other countries require more commitment from students than the United States from its students. The secondary school system in Germany only has a six–week summer vacation, and students can take five years of physics. In the U.S., not as many physics courses are available, and 46% of students in grade 12 do not take a science course. More time needs to be devoted to studying math and physics. This increase could be encouraged by spending less time on nonessential subjects, increasing the hours students are in school, or requiring students to study more outside of class. As the opportunity presents itself, we need to remind and encourage people working on program and curricular development to allow sufficient time for students to study the subject. Quantity time is necessary. There aren't any shortcuts.

4. **Improve teacher preparation in the subject areas.** Considering the level of science and mathematics preparation of the teachers themselves, poor math and science performance in higher education should not be surprising. Almost one–third of the mathematics teachers and one–fifth of the science teachers at the high school level do not have a major or minor in mathematics or science (*Leadership Abstracts*). Less than half of America's high school physics teachers have a minor or major in physics or physics education (American Institute of Physics).

Secondary teachers in Germany are required to have a degree in the major field they teach (*Developing Technicians*). Because they are a major entry point into higher education, two–year colleges play an important role in educating future teachers. Two–year colleges enroll more than one–third of all students taking science, mathematics, and technology courses (*Teaching the Teachers*). Mastering the subject matter that one teaches is very important. In the *Leadership Abstracts* article "Teaching the Teachers: Meeting the National Teacher Preparation Challenge," one of the recommendations is for two–year colleges to "demonstrate leadership in strengthening the undergraduate science, mathematics, and technology courses taken by prospective teachers." Articulation agreements with baccalaureate education colleges should reflect this commitment. As the recommendation states, we need to strengthen the math and science requirements for teachers and encourage more students to major in science and math education.

5. **Change the way physics is taught**. Traditionally, physics has been taught just as a collection of facts or methods for solving cookbook problems by plugging numbers into equations. To truly understand and master physics, students need to learn concepts, reasoning, and critical thinking. Problem solving is important, but, without a conceptual understanding, it is difficult to apply physics concepts to different situations. Changing the way physics is taught to help more students comprehend the subject might reduce the problem of declining enrollments cited earlier.

Some college faculty may be very knowledgeable in their fields but might need to improve their teaching methods. Faculty need to know how to teach students as well as being competent in their discipline. Teaching could be improved by learning skills such as how to ask questions or how to use conceptual exercises. With teaching being the emphasis at two–year colleges, we can take a leading role in this area by encouraging faculty not trained in education to attend seminars and workshops to improve their teaching.

Examples Of Progress

Fortunately, some progress is being made in improving physics and math education. Programs at the state and national level have been implemented. Some results are encouraging, but there is still a long way to go. A few examples of improvements are:

1. Over the last decade, the proportion of high school students who take physics has risen from about 20% to 28% (American Institute of Physics, 1997). Some reasons for this increase might be that people recognize its importance or that different types of physics courses, such as conceptual physics, are being offered to accommodate various levels of math skills.

2. Among high school teachers in their first three years of their careers, the percentage with either a physics or physics–education degree rose from 24% in 1990 to 43% in 1997 (The Physics Teacher).

3. A few projects that have been successful in teacher preparation and changing how physics is taught are Project Discovery and the Two–Year College Physics Workshop Project. Project Discovery began in 1990 in Ohio as a program to train teachers how to better teach science to enhance student learning of mathematics and science (Project Discovery). Middle school, high school, and university faculty collaborated to provide training on inquiry–based learning for teachers. The participants learned both science content and new teaching strategies. The Two–Year College Physics Workshop Project was supported by the National Science Foundation, Joliet Junior College (IL) and Lee College (TX). The purpose of the workshops was to train two–year college physics faculty in the areas of physics education research, curriculum development, and new technology. Over a period of years, over thirty workshops were held, with over 268 two–year colleges participating. The faculty learned about student's misconceptions about physics, new active learning exercises to confront and change the misconceptions, and how to use computers to aid in student learning.

4. The American Association of Physics Teachers has long recognized the importance of learning how to teach physics and finding out what works. It has placed more emphasis on it by adding a Physics Education Research Supplement to the July 1999 issue of *American Journal of Physics* with further supplements planned.

5. An example of a national effort to improve math and science education is The National Commission on Mathematics and Science Teaching for the 21st Century. It is chaired by former Senator and

astronaut, John Glenn. The Glenn Commission was created to gather ideas on ways to ensure high quality teaching in mathematics and science at all grade levels. The plan is to submit a report to the Secretary of Education in the fall of 2000. It will include a small number of recommendations and corresponding action strategies to help ensure that an adequate supply of highly skilled individuals enters and remains in the math and science teaching profession.

Conclusion

While the suggestions above may seem obvious, their implementation is not easy. When students currently have trouble passing the state proficiency tests to graduate, there will be opposition to raise the math and science requirements. With competition from other subject areas and activities, it will be difficult for students to spend more time on math and physics.

One of the challenges to recruiting and maintaining highly qualified teachers in technical areas is that they can earn more money in nonteaching jobs.

Hopefully, the percentage of students taking physics will continue to increase with the result being higher test scores and better job preparedness. Only with people educated better in science and math will we have an opportunity for a bright future.

Carl Sagan is not a person that I would normally quote, but in this instance, he is quite correct:

> We've arranged a civilization in which most crucial elements profoundly depend on science and technology. We have also arranged things so that almost no one understands science and technology. This is a prescription for disaster. We might get away with it for a while, but sooner or later this combustible mixture of ignorance and power is going to blow up in our faces.

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Biography

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