

# **ATTITUDES IN PHYSICS EDUCATION: AN ALTERNATIVE APPROACH TO TEACHING PHYSICS TO NON-SCIENCE COLLEGE STUDENTS**

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In this article, we present an alternative way of teaching conceptual physics for non-science majors by depicting the role of physics in today's technology. The goal of this approach is to increase in the minds of non-science students the acceptance of physics as a useful component in general education, and as a major tool in comprehending the present-day technological world experienced by students outside the classroom.

## **Introduction**

The complexity of today's technology is built on straightforward physical principles that govern modern materials, scientific processes, and physical devices. Students use this technology daily, but many are unaware of how and why its systems and devices work. Students who are generally aware of the usefulness of materials and devices can be motivated to seek an understanding of the principles underlying their operation by starting the learning process with the products (to which the application of physical principles led), rather than by developing first the quantitative laws (that could eventually suggest such applications).

By using this approach, students who would otherwise have inhibitions regarding the scientific method in describing physical laws will become more receptive and may even develop an interest in understanding in detail, and possibly quantitatively, these physical principles. Furthermore, this approach will expose students to many practical applications of today's technology which are not covered systematically in other introductory physics courses.

## **Perception of Physics By Students**

Science in general is a human activity aimed at discovering the order of things in nature and finding the causes producing this order. Physics, essentially the study of matter, force, energy, and their effect upon one another, plays a central role within the sciences because it is the most inclusive, seeking knowledge fundamental to all branches of science.

Physical principles underlie all natural phenomena and constitute the foremost component of understanding the technology that encompasses the tools, techniques, and procedures of modern life.

Given the importance of physics in understanding the world around us, we might predict that learning physics would have enormous appeal for all people. We would expect that large percentages of high school students would be taking physics, and that this would reflect a broad general interest in physics and thereby lead to an increase of students entering careers having physics as a major component. However, statistics from the Virginia State Department of Education of the number of high school students enrolled in physics in the state of Virginia during the 1992-1993 school year, when compared with those enrolled in chemistry, biology, and earth sciences, contradict our expectations. Given student latitude to choose the one science course required for high school graduation in Virginia, only 7.75% out of 190,553 students taking science chose physics. This figure is down from 8.50% for the 1989-1990 school year. For localities in central Virginia, this percentage for 1992-1993 ranged from a high of 11.7% in Chesterfield County to a low of 2.7% in the city of Petersburg.

The overall low percentage of students taking high school and introductory college physics has been a concern throughout the nation for many years. In 1974, John Bailey [1] wrote:

"Without question, one of the biggest problems in college physics teaching is how to reach and draw in students not majoring in the sciences. The size of the opportunity and problem are attested to by the rash of "non-calculus" physics textbooks which has broken out since 1970. Some of these books have taken the approach of making physics easy. This has meant removing most of the numerical aspects. In many cases, what is left is a discussion about physical phenomena, not physics itself. Crucial formulae whose omission would leave just about nothing to talk about are injected without justification. In my opinion this not only insults the student but fortifies the belief that science is foreign, inhuman, magic, something cooked up by and for geniuses, and the best the student can hope for is to memorize enough of it to pass the course."

The following observations point to the fact that a major component of the failure of

physics to attract a broad audience has to do with the unfavorable perception of physics among non-science majors. Kuhn and Faughn [2] state that the "... common attitude of nonscientists,... which often appears when a student enters a physics class,... is one of fear. It will be too mathematical, or it will be too abstract, or it will be too difficult, and so on. Physics is all of these things." Long [3] summarizes the general perception of physics by non-science majors: "I hate physics; it's got to be the most boring subject in the world!" "I'm terrified of physics! You have to know all that math." "Physics is just memorizing formulas, and then guessing the right one to plug numbers into." "Physics has nothing to do with my major. I don't know why they make me take it."

Armed with knowledge of this perception, educators have tried to improve enrollment in physics courses by rethinking both content and presentation to increase their appeal to students. This has resulted in a rash of conceptual physics texts, with varying amounts of mathematical content. However, progress in improving enrollment has been slow. According to a recent study conducted by a consortium of four institutions (Michigan State, Rutgers, Stanford University, and the University of Wisconsin at Madison), freshmen are less prepared now for college-level courses than a generation ago. Science faculty have observed that, "the very best students are still prepared as well as they used to be, but there is a whole larger group that is not. It is like we've lost the middle group of students." [4] Further evidence of this gap was noted in a presentation in the Chautauqua Faculty Development Program in 1989: "The college introductory physics is in trouble. Texts are getting thicker and students are entering with poorer preparation. Methods of reducing failure rate include stretching out the course or instituting preliminary courses."

### **Science Literacy in the U.S.**

The unfavorable perception of physics and the consequently poor enrollment in physics classes are parts of an alarming problem facing this nation. In 1991, even the top 10% of U.S. students, when compared with comparable populations of students from other countries, ranked near the bottom for 13-year-olds in both math and science, behind students from every other economically developed country except Spain [5]. Only 40% of high school graduates take chemistry and only 19% take physics. This situation has direct implications for college-bound students. The proportion of college students who major in engineering is six times higher in Japan (4%) as in the United States (0.7%), and the engineering doctorate for U.S.-born graduate students is almost a thing of the past. Foreign nationals now receive one-quarter of the natural science degrees awarded in the U.S. Moreover, most of the

advanced American graduates enter fields other than those of their secondary school instruction, thereby aggravating the crisis caused by a shortage of qualified science teachers.

Teachers tend to teach the way they were taught. Therefore, if fundamental changes are to be made in ways of teaching and learning science, intervention must begin with those who teach in the lower grades and continue through high school and college level science educators. The quality of middle and high school science and mathematics instruction is linked partially to the shortage of qualified science teachers. For example, 68% of U.S. high school science teachers teach outside their major field of study, 29% of high schools have no physics teacher, 17% have no chemistry teacher, and 8% have no biology teacher [6]. Large numbers of middle school science and mathematics teachers are inappropriately assigned, teaching courses for which they have not been trained. Only about 20% of physical science teachers are teaching the subject for which they were best qualified. Among physical science teachers (physics and chemistry), only 32% had majors or minors in their subjects and only 16% had a minor in science education.

### **Curriculum Practices in Local Colleges**

As the twenty-first century rapidly approaches, the central goal of science education is to prepare a scientifically literate citizenry. As a nation, we want our students to graduate with an essential level of scientific sophistication in order to successfully accomplish their duties as voting citizens and productive members of the American and global economies. Recent national studies have demonstrated an alarming degree of scientific illiteracy not only among the general population in the United States, but also among students at all levels of education [7, 8]. As Robert Hazen and James Trefil of George Mason University state: "Every university in the country has the same dirty little secret: we are all turning out scientific illiterates, students incapable of understanding many of the important newspaper items published on the day of their graduation." [9, 10] Lynn Arthur Steen relates the scene at a recent Harvard commencement where one graduate after another is asked, "What causes the seasons?" Each answers with complete assurance that, since the earth does not travel in a perfect circle, winter occurs when earth is farther from the sun, and summer when earth is closer. But when asked, "Well, then, why is it summer in the southern hemisphere when it is winter in the north?" the confidence disappears as students realize that they don't know the answer to either question [11].

Part of this dilemma lies with how science is taught to non-science majors in college

and with which courses non-science majors are required to take [12,13]. VCU education professor Richard Rezba has written, "While critics were quick to blame everything from curriculum to societal values for the failure, universities share the responsibility for making the improvements necessary to prepare students to work in, contribute to, and enjoy an increasingly scientific and technological society." [14]

An equally disturbing national problem is the significant under-representation of females and minorities studying and appreciating science, as well as so few members of these groups becoming professional scientists and science educators [15, 16]. To females, science is simply not very "user-friendly" in the classroom [17, 18] or sufficiently attractive as a career choice [19].

Data gathered within the past five years indicate that some of these problems exist at VCU [20]. Bill Stump, a professor of chemistry at VCU, has noted: "I became alarmed during the 1970's about the large number of students who withdrew from or failed our general college chemistry course. Lacking in most of these students is a knowledge or understanding of the important general science laws of physics which are necessary to the understanding of many chemical principles."

### **Advances in Physics Instruction at VCU**

Students view the scientific method with varying degrees of discomfort, helping perpetuate the misconception that physics is unapproachably difficult. Contributing to this is the common practice of devising conceptual physics courses for non-science majors as watered-down versions of their calculus-based counterparts. As an alternative, a conceptual physics course entitled *Wonders of Technology* was developed. It uses the alternative method of beginning with today's technological devices and working towards understanding basic principles. The course departs from traditional courses not only by restructuring the sequence of topics, but also by introducing new features crucial for the comprehension of modern technology and the physicist's role in its development. The rationale for this is that, by starting the learning process with the applications of the physical principles (e.g., microwave ovens, NMR tomography, and photocopiers) rather than with the quantitative laws that suggest the applications, the relevance of physics can be more readily established, enhancing student interest and attention.

*Wonders of Technology* exposes students to a wide range of practical applications of

today's technology, connecting physics with other sciences and academic disciplines. The concept of this course has been used in a workshop entitled, "Reality Based Science Instruction for Middle School Teachers," and funded by SCHEV under the Dwight D. Eisenhower Mathematics and Science Act.

### **Description of *Wonders of Technology***

The traditional physics course for non-science majors generally involves the same sequence of topics covered in a majors physics course, appropriately diluted. Typically, the sequence of topics in a two-semester traditional course are: time and motion, interactions and forces, energy, waves, electrical and magnetic phenomena, atoms, and modern physics. *Wonders of Technology* restructures this sequence and discards the traditional introduction of concepts. Rather, this course begins with real technology and dissects the modes of function and materials used in order to introduce physical concepts. Along the way, the importance of physics is relayed by using examples that are crucial for the comprehension of physics and the roles of mathematics and physical sciences in the development of the products or techniques under discussion. The new format also stresses project/laboratory/hands-on components.

### **Course Content**

Physics courses involving case studies in technology enrich a liberal arts curriculum through motivation for science learning, introduction to the techniques of problem formulation and solving, and bringing together disparate academic disciplines. Consider an example: Magnetic Resonance Imaging is a novel, noninvasive method used to identify cancerous tumors in the brain. It is based on the interaction between a magnetic field and atomic nuclei situated in the brain tissues. This method was developed through knowledge of a physical phenomenon called "nuclear magnetic resonance," and it was applied to live tissues. This was made possible by clearly understanding the chemistry and biology involved in the interaction. Furthermore, analysis of the immense amount of raw data to be processed into useful information was made possible by the use of high speed computer technology. Using numerous case studies that are pertinent to the everyday lives of non-science majors, *Wonders of Technology* introduces topics in the following sequence:

- (1) The concepts of work, energy, and conservation in a philosophical and common sense perspective;
- (2) Materials (relationship between microscopic structure, physical properties, processing

- and the environment);
- (3) The structure of matter, basic interactions, atomic structure and its influence on the macroscopic properties of the materials (possession of adequate mechanical properties is essential for the existence and continuity of all forms of life);
  - (4) Devices (concepts of forces, work, and energy are developed at the macroscopic level using levers, gears, pulleys, springs, photography, printing, music, electricity, and computers to explain movement, friction, energy, waves, electric forces and currents, and how these are harnessed);
  - (5) Processes (influence of processing materials on their resulting micro-structure, macro-structure, and overall properties).

### Methodology

*Wonders of Technology* stresses project/laboratory/hands-on components. We describe here in some detail the major characteristics of the methodology employed in the course: vertical integration design, project centered format, and interdisciplinary content.

- (1) Vertical Integration of Material. Although developed at the freshman, non-science student level, *Wonders of Technology* is designed for easy vertical integration, so it can serve as the basis for redesigning 200-level physics, biology, and chemistry courses for science majors.
- (2) Project/Laboratory Centered Unit Format. Lecture and laboratory components are integrated in a logical sequence and stress the following objectives:
  1. Students should learn something pertinent to their lives;
  2. Students should develop a desire to learn more about the phenomena under study;
  3. Students should reach a conceptual/qualitative understanding of natural phenomena and of their relevance to science, technology, and society.

The three course segments (I, II, and III below) provide for interaction between instructor and students for each topic.

Segment I: Lecture Component The instructor's presentation uses multimedia and is interactive. During this period, the instructor introduces topics from life-related experiences. These topics emphasize the interdisciplinary nature of the phenomena to be examined and the evolutionary nature of the technology, stressing historical, cultural, and philosophical relevance. Topics in this phase are introduced in ways that require problem solving and that raise more questions. Additional information related to a topic (from the same discipline or

a related discipline) is frequently introduced by requiring individual students to conduct hands-on projects and present their results to their classmates.

Segment II: Laboratory or Investigative Activity Small groups of students develop investigative activities (designing an experiment to test a certain hypothesis) or carry out assigned projects (building a radio, for example) that have relevance to the topics developed during Segment I. For the investigative activities, students are presented with physical concepts or issues and required to design an activity that illustrates them [21, 22]. Students first prepare and submit an outline of the project, its goals, and a list of materials necessary to conduct the activity. Projects are reviewed by the instructor and revised as necessary; then, the group is given the requested materials. Following completion of investigative activities, the results are summarized by the students and presented to the class. Both investigative activities and assigned projects are conducted in three stages, each of which could be considered as an end in itself, and are designed in order of increasing complexity, depending on the degree of skill of the group performing them. Upon completion of the first stage, students earn a minimum grade of “C”. Students who satisfactorily complete the next level earn a “B”, and those who complete the third and most advanced level earn a grade of “A.”

Segment III: Enrichment Components A necessary complement to the large lecture and/or the conclusion of the hands-on projects is for students to discuss the topic, its relevance to personal life, technology, and other sciences. For large classes, weekly "breakout" sections of 20-30 students are scheduled for discussion of enrichment topics. This type of “socialization” often involves discussions focused on the interdisciplinary nature of the phenomena under examination. Current events are emphasized by using recent news clippings or articles to explore underlying ethical issues and political themes. Prearranged debates are an especially useful tool to convey the concept that ethical dilemmas related to physics and the sciences often have more than one solution. Students write essays on assigned topics, go on field trips, and use interactive computer programs.

- (3) Interdisciplinary Content Students in *Wonders of Technology* (or similar courses with interdisciplinary approaches) gain a broader understanding of all science, not just one particular field, thereby enhancing their scientific literacy and increasing their retention of science-related knowledge. Furthermore, students learn how to obtain additional information on a scientific subject if required by their occupation or stimulated by personal curiosity at a later date. Making *Wonders of Technology* interdisciplinary requires a combination of elements of physics, biology, chemistry,



geology, and the humanities in a manner that helps students develop the ability to think critically about technical issues so they can use basic scientific principles to make informed decisions throughout life. Approaches used in this course span a wide range of teaching methodologies which include: multimedia presentations (laserdisc, CD-ROM, etc.) in the large lecture (“Segment I” above); objective investigative laboratory exercises (“Segment II”) designed to promote critical thinking, communication skills, and scientific literacy; and “guided” recitations (“Segment III”), in which small groups of students criticize and challenge contemporary scientific and technical issues on both personal and global scales.

Multidisciplinary topics capture student interest. An essential tool in this course is the use of topics of contemporary social or political interest. Once the topic is introduced, it is a simple matter for the instructor to show the physical, biological, and chemical processes beneath the issue. The method continues as the class examines social and ethical processes that affect potential solutions or uses of technology. Some examples include:

(a) Light of Life The topic of photosynthesis is approached by exploring: 1) the cellular structure of a plant leaf, the power plant-like chloroplasts within leaf cells, and the process for exchange of oxygen and carbon dioxide gases; 2) the chemical reactions that occur during the light-independent portion of photosynthesis; and 3) the physical and chemical phenomena that occur during the light-dependent portion of photosynthesis.

(b) Microwaves Microwaves belong to the electromagnetic spectrum, resemble radio waves, and are used in a number of physical and biological applications; including, microwave ovens found in most homes, satellite communication systems, and the small dishes now used by many homeowners for direct TV transmission from satellites.

(c) Magnetic Resonance Imaging MRI is a relatively new physical technology used both as a diagnostic tool for determining tissue damage and as a research tool in cognitive neuroscience. MRI is derived from the field of nuclear magnetic resonance which was first used by physicists and chemists to study detailed chemical features of molecules. MRI technology is based on the fact that atomic nuclei behave like compass needles in the presence of a magnetic field. MRI works because hydrogen

nuclei (protons), making up 80% of animal bodies, can be polarized by being placed in a strong magnetic field generated by an MRI apparatus. The machine then recognizes images produced by the relaxation pulse as the hydrogen nuclei return to their former, randomly-oriented arrangement.

Other topics in brief include:

(d) Depletion of Oil and Natural Resources The flow of energy through ecosystems, geology, recycling, economics, and intergovernmental relations are discussed.

(e) Ozone Depletion Interaction of UV waves and chemical bonding, meteorology, chemistry, global warming, and air pollution are discussed.

(f) Overpopulation Energy consumption and effects on the environment, entropy and global warming, technology, and energy co-generation are discussed.

(g) Electromagnetic Radiation Effects Global communication, as well as physiological, health, and mutagenic effects are discussed.

## Conclusion

The *Wonders of Technology* course and the general science instruction methodology discussed in this paper reflect a fundamental change in the underlying paradigm of science and science instruction. Science was formerly a “frontier” to be explored for the sake of knowing and technology was implemented without personal or corporate responsibility. Knowledge of physics and the other natural sciences, and application of the scientific principles have led to a technological revolution known as the “industrialization of society.” Our perception of the current state of science is that technology and society are so interrelated that it would be difficult if not impossible to treat a single scientific field as autonomous or to pursue scientific inquiry without evaluating the multitude of technical and social ramifications of that study. Based on our experience with this and similar courses, we predict that interdisciplinary course content in all courses (both sciences and humanities) will enhance science literacy, retention of scientific knowledge, and the relationship between science and emerging technology. We contend that the instructional paradigm presented here is, in fact, a very reasonable and socially sensible way to teach science courses to non-science majors.

The *Wonders of Technology* course appears to have significantly affected students' perception of physics. Those attending the first *Wonders of Technology* course commented very favorably (on their anonymous Student Evaluation of Instruction forms) about the lecture methodology employed. Students also expressed great satisfaction with the investigative nature of the laboratory component, related in part to the feeling that they were more in control of their educational experience. We believe that investigative labs require students to be active participants and stakeholders in their education and that the thought processes required to perform the investigative labs allow students to "take home and apply" the material they have learned. Students seem to enjoy and appreciate this. ■

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