Harvard Project Physics: Development, Structure, And Adaptability

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Abstract

During the 1970's, *Harvard Project Physics* was a popular curriculum used in high school physics classrooms, and sought to change the way physics was taught. The materials created were revolutionary and had a positive impact on the teaching of high school physics. The objective of this paper is to explore the development and structure of *Harvard Project Physics* in an effort to better understand the scope, sequence, and relevance of this historic project. This exploration will serve as the foundation for exploring the adaptability of *Harvard Project Physics* to the modern classroom.

Introduction

Harvard Project Physics was arguably one of the most influential physics curriculums used in the United States. Although this program is not in use today, its impact is evident in the field of science education, and its materials are still adaptable and useful in teaching high school physics.

Another curriculum, Physics Science Study Committee (PSSC) Physics, was developed with similar goals. It was used in the 1960's, but failed because teachers did not have appropriate training and "the typical high-school teacher is not 'a surrogate scientist'" (French 1986). The authors of *Harvard Project Physics* learned from the mistakes of PSSC, and provided workshops and extensive notes on how the teacher could use the materials to maximize instructional effectiveness.

However, the curriculum is not without shortcomings. This paper will explore the development and structure of the curriculum and identify its strengths and weaknesses. Although the *Harvard Project Physics* materials are currently being revised, by David Cassidy at Hofstra University (Holton 2003, 785), this paper discusses the original materials from the 1970's. Additionally, since the original *Harvard Project Physics* materials are being used, the paper will attempt to present the validity of using older materials within today's classrooms.

Program Creators

F. James Rutherford was born in California in 1924. Shortly after the attack on Pearl Harbor, he joined the Navy. After the war ended, Rutherford completed his bachelor's degree at Berkeley, and then continued to obtain a master's in science education from Stanford. After teaching high school physics for several years, he went to Harvard where he received his doctorate in science education in 1961. Dr. Rutherford returned to teaching high school physics in California for a few years, but departed for Harvard in 1964 to become a professor of science education (Lange 2005, 4).

The second contributing member of *Harvard Project Physics* was Gerald Holton who received his bachelor's degree from Wesleyan University in 1941 and a master's degree in 1942 before continuing on to obtain a doctorate in physics from Harvard in 1948. Dr. Holton became a professor of physics at a number of universities before beginning work at Harvard, where he worked in both the physics and history of science departments (Holton 2009).

The final member of the *Harvard Project Physics* team was Fletcher G. Watson who graduated in 1933 from Pomona College and went on to receive his doctorate in astronomy from Harvard in 1938. Dr. Fletcher did post-graduate work in the Harvard observatory and served in the Navy during WWII. After the war, he returned to Harvard where he became a faculty member of the Science Education department (Watson 1990).

Aims

When the authors set out to create *Project Physics*, they first put together a set of concise goals for the course. They were:

1. To help students increase their knowledge of the physical world by concentrating on ideas that characterize physics as a science best, rather than concentrating on isolated bits of information
2. To help students see physics as the wonderfully many-sided human activity that it really is. This meant presenting the subject in historical and cultural perspective, and showing that the ideas of physics have a tradition as well as ways of evolutionary adaptation and change.
3. To increase the opportunity for each student to have immediately rewarding experiences in science even when gaining the knowledge and skill that will be useful in the long run.
4. To make it possible for instructors to adapt the course to the wide range of interests and abilities of their students
5. To take into account the importance of the instructor in the educational process, and the vast spectrum of teaching situations that prevail. (Rutherford, Holton, & Watson 1975, vi)

These aims contain many of the goals of the high school physics teacher, but then go above and beyond. The first item that was an innovative idea for the 1960's was that the students are the focus. Each aim, either directly or indirectly, references the students, which implies that they are the core reason for the project. This goes along with a student-centered course, in which students direct their learning instead of traditional lecture where the pacing is determined solely by the instructor. This is now more commonplace in curriculum development in high school physics (Arons 1997).

However, unlike most courses, there were also aims that include the needs of the teacher, and imply that they are skilled professionals that can shape the materials as they see fit. The authors wanted to make sure that the course they were going to create could be adapted by *any* teacher to fit their students' needs. Every classroom of students is different due to students differing ability levels and prior experiences and it is important that the teacher can easily adapt the materials to fit the students without interrupting the integrity of the course. Beginning with these goals in mind would help the authors to focus their efforts to create the best course possible at that time.

Development

The *Harvard Project Physics* curriculum was developed in three phases. In the first phase,

> [t]he three authors collaborated to lay out the main goals and topics of a new introductory physics course. They worked together from 1962 to 1964 with financial support for the Carnegie Corporation of New York, and the first

> version of the text was tried out with encouraging results. (Rutherford, Holton, & Watson 1975, v).

In the second phase, the authors examined the preliminary student achievement results, and worked to receive several major grants from U.S. Office of Education and the National Science Foundation (NSF), beginning in 1964. Additionally, there was financial support from the Ford Foundation, Alfred P. Sloan Foundation, Carnegie Corporation, and Harvard University. It was at this time that the project was officially entitled *Harvard Project Physics*. With a great deal of funding for the project, there was a large number of staff and consultants hired. These collaborators consisted of physicists, astronomers, chemists, historians, philosophers of science, college and high school teachers, science educators, psychologists, evaluation specialists, engineers, filmmakers, artists and graphic designers (Rutherford, Holton, & Watson 1970b).

In the third phase of the project's development, the team concentrated on developing, and then later, conducting training programs for teachers. Additionally, a great deal of time was spent analyzing data and writing reports on their findings and the successes of the course. This is also the time at which the project started to approach the fourth and final aim, which included the addition of materials that would "reshape the course for special audiences" (Rutherford, Holton, & Watson 1975, v).

In 1973, President Nixon became "disenchanted with scientists" (Holton 2003, 784) because many of them were against his politics. "One by-product of Nixon's displeasure was a phasing-out of sections of federal science funding; the money for teacher training was fairly soon cut off" (Holton 2003, 784). This made it extremely difficult for the staff to have a large impact on the education system. After a revision in 1981, the publisher could not envision doing another revision "because of its precarious financial condition" (Holton 2003, 784).

Structure of Curriculum Materials

For each unit within the *Harvard Project Physics* course, there are several materials. These include a textbook, teacher guide, handbook, reader, tests, and film reels. These materials will be described below.

The textbook and teacher guide are similar. They contain the same content, but the teacher guide adds notes for the instructor and questions to ask the class. The textbook was written in an informal style that is a pleasant change from the formal approach of many textbooks. The various phenomena are explored before definitions are given, but not prior to using the technical terms, such as average speed, which goes against the advice of Arons (Arons 1997, 27). The example problems that are given within the text are laid out extremely well. For example, an equation is given, e.g. "$v_{av} = d / t$" (Rutherford, Holton, & Watson 1975, 24), the conceptual names applied, e.g. "average speed = distance traveled / elapsed time" (24), values with units, e.g. "average speed = 50.0 yd / 56.1 sec" (24), and then numerical answer with units, e.g. "0.89 yd/sec" (24). The authors have made the process of algebraic problem solving more accessible by breaking the problem into a series of steps, which is then explicitly explained. This allows students to see each step of the problem clearly, making it easier for them to complete similar problems on their own (Arons 1997).

There is a great deal of history that is included in the textbook, for example selections from Galileo's *Two New Sciences*. This is not surprising knowing that Rutherford studied in the

History of Science Department at Harvard (Lange 2005, 4). The history allows students to understand how ideas developed, as physicists tried to piece together many of the concepts that are now nearly common knowledge to the physics teacher. This is an opportunity to see physics as a human activity. In addition, the authors have included a time line, which neatly lays out the major historical events, and influential people of the times divided into six categories: government, science, philosophy, literature, art, and music. This allows students to get a better understanding of the events and influential figures of the time period in which various scientists were prominent.

In the student handbook, the authors boast it as the “guide to observations, experiments, activities, and explorations, far and wide, in the realms of physics” (Rutherford, Holton, & Watson 1970a, 4). The book urges that physics is not to be read, but to be experienced (Arons 1997, 29). There are an extraordinary number of activities and the authors note, “you will need to pick and choose” (Rutherford, Holton, & Watson 1970a, 4). However, despite the smattering of topics, the handbook retains consistency. The introduction also urges students to complete any activity of interest, even if their instructor does not specifically assign it to them.

The student readers were designed to provide the students with a variety of supplemental materials either to enrich the material in class, or to delve deeper into the physics. "For those seeking a deeper understanding of mechanics, [the authors] particularly recommend the article from the *Feynman Lectures on Physics*" (Rutherford, Holton, & Watson 1970b, 9). These lectures and the other articles that are considered for those seeking a deeper understanding are at a collegiate level, with some involving calculus. For those that may find reading lectures by Feynman daunting, there are many articles involving art, sports, and practical applications. Several of the articles were written by famous physicists. This gives, for example, Newton's explanation of dynamics. It affords students the opportunity to put themselves in the shoes of famous scientists and read how they describe concepts that may now be seen as elementary. Interestingly, there is a paper entitled *Four Pieces of Advice to Young People* by Warren Weaver (1966) giving students advice for their future, which opens with the author stating that he is aware that those reading this article will ignore his advice. This casual style makes this and many of the articles intriguing to read to students. These readers also made physics seem more accessible to students.

Among the staff of the *Harvard Project Physics* team were filmmakers. “There were films produced including an award winning film on the life of Enrico Fermi” (Lange 2005, 5). The film entailing the life of Enrico Fermi is a phenomenal account of his life and research and includes interviews by other physicists and their relationship with Fermi. Another film, *People and Particles*, follows a research team that is studying particle physics. This film gives students a look into the life of scientists and also the scale of particle accelerators at the time. Without the foresight of the project, this footage would have never been captured. These films are another testament to the creators' dedication to the field of physics.

Shortfalls and Strengths

The *Harvard Project Physics* course was without a doubt a successful curriculum with approximately "20% of all high school students taking *Project Physics*" (Holton 2003, 783) in the seventies. However, with the advances that have been made in physics education over the past 20 years, it is no longer the premier curriculum with projects like the Modeling curriculum (Wells, Hestenes, & Swackhamer 1995) starting to gain momentum. However, this does not mean that its components are not applicable and cannot be used to teach high school physics.

One of the biggest criticisms with *Harvard Project Physics* is that the materials often give the students the formulas and names prior to developing the concepts. Arons suggests the use of "operational definitions" (1997, 18) that are developed prior to the formulas and typical textbook definitions. An operational definition involves "describing the actions and operations one executes, at least in principle, to give these terms scientific meaning" (Arons 1997, 18). Students are encouraged to tell "stories" that describe the process for obtaining values for concepts like velocity (Arons 1997, 18). This is especially important "since the words [used in physics] are drawn from everyday speech, to which we give profoundly altered scientific meaning, only vaguely connected to the meaning in everyday speech" (Arons 1997, 18). The *Harvard Project Physics* materials develop operational definitions, but only after the formulas and formal definitions have been discussed. This is a weakness in the curriculum because physics terms are also found in the vernacular and "students remain unaware of the alteration unless it is pointed to explicitly many times-not just once" (Arons 1997, 18). This weakness could lead students into trouble and not properly address their preconceptions in kinematics and dynamics.

In my experience, recently in education there has been a great push for literacy and the inclusion of real world examples in science courses. The *Harvard Project Physics* materials demonstrate how literacy and real world situations can be integrated into a physics course. The inclusion of the readers for each unit allow for copious amounts of readings related to physics, helping to foster the literacy that many schools are now attempting to incorporate in all disciplines. In addition, the overall majority of examples in the textbook are physical situations, most of which the average students would have had direct experience.

The *Harvard Project Physics* materials do a phenomenal job of outlining the thinking held at various points in history. Before delving into Galileo's revolutionary ideas, the text describes medieval concepts. This is interesting because the development of science is not often discussed in history courses. The students will be familiar with the medieval time period, but this is a different take on the era. Aristotle and Galileo's ideas about motion are discussed in a concise manner that would not be difficult for the students to read in an evening. The sections on Aristotle and the medieval eras could easily be given during the unit. The remainder of the material should only be given after motion is understood and acceleration is discussed because Galileo proposed the concept of uniform acceleration. The incorporation of such materials helps to develop student's appreciation for the ever-evolving nature of science, instead of validating the idea that science is a static, solitary field, which, in my experience, is held by many students.

Applicability to New York State Standards

When analyzing curricula, it is often useful to determine if the curricula align with state standards in the area. Although the *Harvard Project Physics* materials were intended for teachers in any state to use, they will be compared with the New York State standards because of New York's clear standards for high school physics and because this is the state of greatest personal interest.

First, we will discuss the historical aspect. The beginning of the Physics Core Curriculum states that students should have an appreciation for the developments made throughout history (NYS, 2005, p. 4). This is easily met by the *Harvard Project Physics* materials. The materials, in particular the textbook, guide students through the beliefs of society at various points, and explain concepts from diverse perspectives. An example of this is motion being explained in Aristotelian, Galilean, and finally Newtonian point-of-views. This will help the students to understand the thoughts held at various points in history and have a sense of how these ideas progressed. Additionally, this will help to foster scientific literacy, because the materials address some marks of scientific literacy proposed by Arons (1997).

The original *Harvard Project Physics* materials would prepare students for end of year exams, the Regents in New York State. However, with the advances that have been made in physics education research, there are recent curriculums that have proven to be more successful in the preparation of students (Jackson, Dukerich and Hestenes 2008). Since one of the aims of *Harvard Project Physics* was for the materials to be easily adapted by each teacher, the materials are suited to enhance recent curricula. An effort has been made to incorporate the *Harvard Project Physics* materials with the Modeling Curriculum from Arizona State University (Lindley 2010). This combination enables the instructor to take what the *Harvard Project Physics* materials did best and integrate them into leading physics education research to give students the best possible education. Any combination that incorporates *Harvard Project Physics* materials will effectively prepare students and give them a more rounded view of science as a field.

Conclusion

Harvard Project Physics was a curricular masterpiece. It was the first commercially produced and widely distributed curriculum that successfully incorporated history and real-world situations with physics. The additional readings help to develop literacy within science classrooms. Additionally, the creators implemented workshops to help educators develop the necessary skills not only to use the materials, but also to effectively educate students. This training is essential if the teachers are to maximize the materials effectiveness in their classrooms. This model of training workshops has since been adopted by other curriculum developers (Jackson, Dukerich and Hestenes 2008). Having personally attended several of these workshops, they are invaluable and the curricular materials would be nowhere near as successful without them. By creating the workshops, the *Harvard Project Physics* team sought to make their curriculum as successful as possible. The forethought of Dr. Rutherford and his colleagues to hold such workshops is yet another testament to their dedication to creating a successful physics curriculum.

Harvard Project Physics gave students an added appreciation for the development of science. It is a course that altered how all future science curricula would be developed. *Harvard Project Physics'* applicability to today is a testament to the authors' dedication to the field of physics education.

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