# Opinion Piece: Gerald Holton's Contribution to Physics Education

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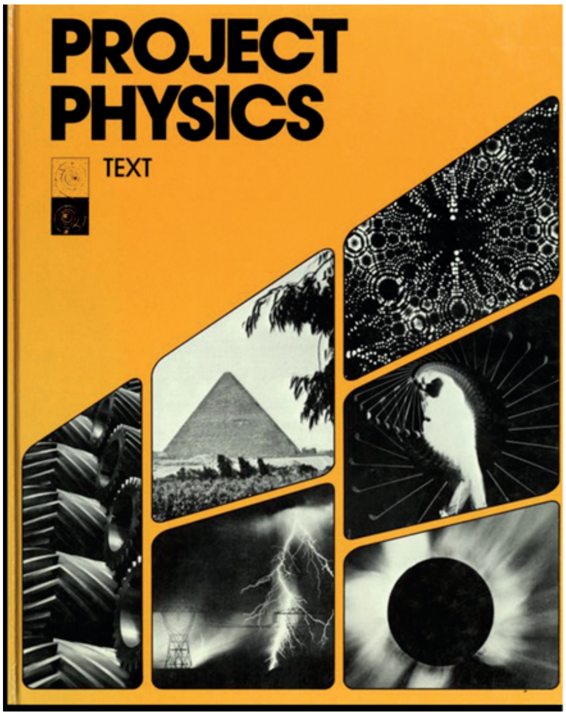
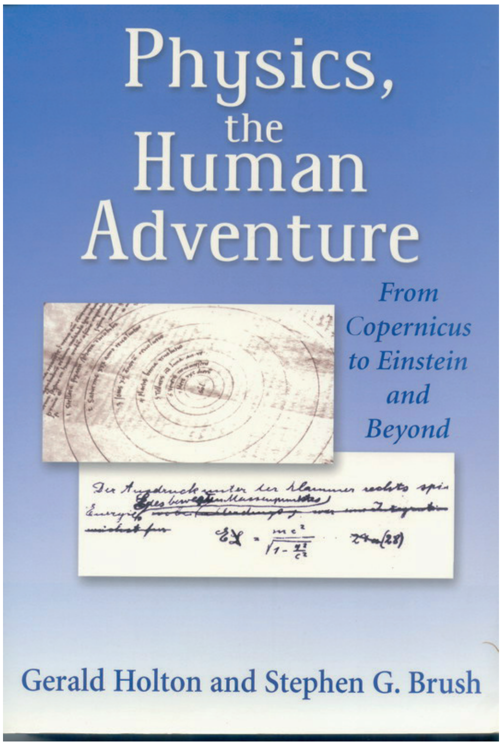
Gerald Holton's 100th Birthday (23 May 2022) is a fitting time to write about one of his most enduring contributions to science education, the Project Physics Course. Project Physics (Rutherford, Holton & Watson 1981) provided students a humanistic approach to physical science. A principal legacy of the project is the evidence that science education conceived as part of a liberal education can provide students with meaningful achievement with respect to science content as well as a more positive attitude towards physics than traditional instruction. More broadly, from Holton's writings, we come to understand that his humanistic approach to education extends to the gender gap through his contribution to *Who Succeeds in Science?* (Sonnert & Holton 1995), and his contribution to *A Nation at Risk* (Gardner 1983) which addressed the needs of all students in the United States.

For what follows the humanistic approach can be interpreted as a respect for all learners irrespective of gender, race, ethnicity, and culture, and the recognition of humanity's wonderful capacity to understand the natural world. This interpretation appears to be in harmony with Holton's work as discussed below and operationally with the development of Project Physics




It may be said that the story of Project Physics begins with Holton's course at Harvard for which he wrote the text *Introduction to Concepts and Theories in Physical Science* (Holton 1952/1985/2001). First published in 1952 (revised with Stephen Brush in 1985, revised and re-issued in 2001 as *Physics: The Human Adventure*) it was the outcome of his experience teaching physics and general education in the physical sciences. The Introduction to the text presages what was to come with Project Physics. Holton wrote that he wanted science to be an "integrated and exciting intellectual adventure" for all students in his course, not just those who would go on in science. In particular, his concern was that students should develop a coherent and connected understanding of science and society. Holton cites a metaphor from a section of the Harvard Report on General Education in a Free Society that often science courses provide students with knowledge as if they were isolated bricks.

Those who go on in science build structures of understanding from these bricks. But for the majority of students in a science course, all that they are left with are bricks. Holton's objective in writing his first text was to bind these bricks for all students with the history and philosophy of science and connections to other intellectual endeavors. This followed from his belief that students who do not intend to become scientists "want to see also what place physics has in the total reality, in the context of all intellectual endeavors: and unless we help them, nobody will" (Holton 1964).




It is from here that the history of Project Physics flows as documented by Holton (1968, 1978). In brief, in 1960 Holton was approached by James Rutherford, a Harvard science education graduate student who had been using *Introduction to Concepts and Theories* to teach high school physics in California. Rutherford suggested to Holton that a version appropriate for high school students be written. A sequence of events seeking funding ensued and with the addition of Fletcher Watson (1912-1997), professor of science education at Harvard, the three began work with a small grant from the Carnegie Foundation in 1962 to develop such a curriculum. In October 1963, the NSF called a meeting of scientists to prompt a second high school level physics course to complement that developed by the Physical Science Study Committee (1960). Holton responded to this request and with Rutherford, Watson, and himself at the helm, Project Physics was off to the races as of 1 July 1964 with a large number of contributors developing the text, lab manuals, supplementary reading materials, teachers' materials, and film strips (Holton 1967). All of this was tested through teacher workshops and school trials.

By 1970, Project Physics was being used by roughly 300,000 students nationally thereby reaching roughly 20% of the high school students taking physics (Holton 2003). Internationally, *Project Physics* was translated for use in Italy, Portugal, Japan, China, Australia, and Canada. In each case the translation came with the stipulation that the content be adjusted for the local culture. For Canada there were both an English and a French Quebec version with appropriate shifts in references for the local culture (Holton 1978).

We remember Project Physics today as a beacon for what can be achieved with a science curriculum connected to the history and culture of science. Project Physics was based on Holton's intuition that inclusion of the physical sciences in a liberal education that addressed all students, not just the 20% already motivated to study science, required a coherence and connectedness with culture, and that such connections needed to be made through the history of science. Those of us engaged in science teaching through history and philosophy arrive at this intuition early in our careers. It seems so obvious. Analogously, we are the 20% who are already motivated to engage in this pedagogy. But in the United States with class time short, with the physical sciences taught in high schools targeting performance on standardized exams, and the introductory college courses offered as service courses at the university level, justification for time to be spent connecting physical science (or any of the sciences) to society and culture is a battle both for time and with our colleagues whose interests are more narrow.

The competition for class time is such that the history and culture of the scientific enterprise almost invariably loses out. Ahlgren and Walberg (1973) make this point in their contrast of Project Physics with the physics curriculum developed by the Physics Science Study Committee (PSSC 1960). The stated content objective of the PSSC was "to develop a physics course that emphasizes the essential intellectual, aesthetic, and historical background of physical science" (PSSC 1957), but the product itself was almost strictly devoted to science content. By contrast, Project Physics explicitly included the history of science in the text, assignments and tests. From this graded inclusion students understood that the teacher valued their learning of the history and culture of science, as well as the physics content *per se*.

When material is added to a course, other material must be displaced. The selection of topics in the Project Physics text delved into the standard concepts of physics (motion, light, waves, electromagnetism), as well as more modern atomic theory and quantum mechanics, but jettisoned some of the more technical exercises of the traditional texts. Despite this shift from more traditional physics content, Project Physics students still performed as well as students in a traditional course on a standardized test (in this case, the New York State Regents exam). Evaluation studies further demonstrated that students who took the course had improved attitudes towards physics as compared to students who took a traditional physics course or PSSC Physics (Ahlgren & Walberg 1973). We might also very reasonably speculate that these students also learned some history and had an improved understanding of how science is done.

As Holton has written, if asked whether the effort of teaching the physical sciences from a humanistic perspective is worth losing what must be displaced of the physics to include the "extras" of history:

> The humanistic approach to science teaching has been tried, and it works. If I were to leave out what you regard as extras, I would be apt to teach *dead* science, and my students would know it. Instead, I shall take on the more difficult task that my sense of obligation to my students requires, and they will thank me for it." (Holton, 2014)

While Project Physics provides those of us who believe in a humanistic approach to science education with talking points based on its success, there are transcendent themes in Holton's writings that speak to the current times when educators are faced with changing student demographics. These are evident in Holton's subsequent contributions to *A Nation at Risk* (Gardner 1983) and to gender equity in the sciences with *Who Succeeds in Science?* (Sonnert & Holton 1995). These promote a broader humanistic approach to educational reform that recognizes that all students should have the opportunity to succeed in science. In *A Nation at Risk*, to which Holton contributed significantly, the humanist expectation of education is succinctly stated in a very Jeffersonian way:

> All, regardless of race or class or economic status, are entitled to a fair chance and to the tools for developing their individual powers of mind and spirit to the utmost. This promise means that all children by virtue of their own efforts, competently guided, can hope to attain the mature and informed judgement needed to secure gainful employment, and to manage their own lives, thereby serving not only their own interests but also the progress of society itself.

These words resonate with me as the broad objectives of my own pedagogical activity. I am a physicist and science educator who prepares pre-service elementary teachers, pre-service science teachers, provides professional development for in-service physics teachers, and works with teachers in grades K-12 to teach science in high need school districts. For my work, I am grateful to Project Physics for validating my belief that teaching the conceptual history of science is a good way to teach the nature of science to teachers (Garik et al 2015; Winrich & Garik 2021) and that in doing so I may at least indirectly affect the attitudes toward science of their students who are our future citizenry. It is when I work with teachers in a high-need school district with a majority of students from immigrant families, and for whom English is a second language, that the need to find ways to connect science to different cultures becomes essential. Project Physics taught us the value of connecting students to the culture of science, but making such connections meaningful is a two way affair. Here education research and best practice pedagogy have caught up to Holton's prescient intuition for the value of a humanistic approach to science teaching. Culturally relevant/responsive teaching, also referred to as culturally competent teaching, seeks ways to connect students' home and neighborhood cultures with their school studies (Gay 2013) and help all students feel that they belong in science class. Project Physics showed such sensitivity to making connections to students' culture in the stipulation that the translations of Project Physics for other countries make alterations to fit the local culture, and in the promotion of gender inclusiveness in such ways as with the pictures in the frontispieces of the Project Physics Readers of young women studying.

Embedding students' culture in science instruction does not conflict with a humanistic science curriculum that includes the history of science ideas and the contributions of great scientists of the past. That provides a general affirmation of humanity's capacity to understand the natural world. Culturally responsive teaching further engages students by providing connections with their own culture and identity to help them recognize that they too can contribute to our understanding of Nature. The global growth of science over the past fifty years, as well as research that has recognized uncredited women scientists, has made this easier with ever more stories of women and scientists of color making contributions in all the sciences.

Reading the list of contributors to Project Physics (Holton 1967) and to PSSC Physics (PSSC 1957), the names and genders tell a story of white males of European descent dominating the development of the curriculum. One might imagine Holton constituting a committee in 2022 to develop a humanistic physical science curriculum and how its membership would reflect the gains made in the participation of women and the many ethnic groups/persons of color in the United States in the sciences. Such a modern committee would have no difficulty adopting the humanist approach of Project Physics while finding ways to broaden the course's appeal to a larger audience with sensitivity to the need for the inclusion of women and students of color. This would address concerns raised in *A Nation at Risk* (Gardner 1983) as quoted by Holton (2003b):

> Our concern, however, goes well beyond matters such as industry and commerce. It also includes the intellectual, moral, and spiritual strengths of our people which knit together the very fabric of our society. ... A high level of shared education is essential to a free, democratic society.

Project Physics arose out of a need to engage students in physics courses at a time when enrollment in high school physics had dropped precipitously, a time when the national interest appeared to be served by increasing the scientific knowledge of high school graduates, and the post-Manhattan Project time when leading scientists were concerned about the citizenry's understanding of the scientific enterprise. Project Physics addressed these issues by humanizing physics education with a resultant improvement of student attitudes, while maintaining ambitious standards for physics learning.

It is now more than 50 years after the completion of the first draft of Project Physics. The world has changed since then, but the needs of science education, and physics education, have not changed greatly. In an age of alternative facts and disinformation there has never been a greater need for science education. When as educators we make our arguments for improving science education, we should rely on the lessons learned from Project Physics and Gerald Holton's insights into students' needs for connections between the culture of science and their own identity.

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