The contributions of science educator F. James Rutherford: Harvard Project Physics and Project 2061

Catherine Lange
Buffalo State University

Abstract
This research chronicles over sixty years of the contributions of science educator F. James Rutherford. Rutherford is one of the three masterminds behind Harvard Project Physics and more recently, creator and founder of the American Association for the Advancement of Science's Project 2061. A long-term reform strategy, Project 2061 currently serves as the standard and guiding doctrine for the reform of science education foundational ideals and pedagogical premises in America.

Introduction

Over the past century, the attention and focus on science education in American K-12 public schools has been tumultuous, rising to a place of dominance in post-Sputnik periods and declining to a state of near-invisibility in the wake of No Child Left Behind (NCLB) legislation that places emphasis on reading and mathematics and standardized testing. Although NCLB has included testing in science, schools are not held publicly accountable for student science scores as they are for reading and mathematics. The post-Sputnik funding that was spurred on by societal awareness and cultural acceptance of the importance of science is now, unfortunately, only a moment in history. The de-emphasis of science in present day K-12 education is not only vexing but also dangerous if we consider all the science-based issues the world is now facing.

This paper will examine one piece of the history of science education involving one of the most influential science educators of the twentieth century, F. James Rutherford. Rutherford began his career as a science teacher in the outskirts of San Francisco, California. Upset by the lack of sound science curriculum and teaching resources, and lacking background knowledge, Rutherford decided to study the history of science at Harvard. The first part of this story concerns Rutherford's intention to develop practical and effective physics materials to help the high populations of second-language learners he had as students. What began as a few lesson plans burgeoned into a viable curriculum centered at Harvard University. Rutherford joined science educator Fletcher Watson and physicist/science historian Gerald Holton and together they created Harvard Project Physics (HPP) in 1962. By its completion in 1970, it was a massively expansive and comprehensive program of textbooks, worksheets, overhead transparencies, tests, readers, full-feature films and a plethora of teacher and student resources too numerous to mention. The program offered teachers content and resources that they would otherwise not have easy access to such as historic experiments, literature, assessment tools and depictions. Additionally it provided student-friendly information about cutting edge scientific research projects that average kids could read and understand. Its success was partly due to the comprehensive and interdisciplinary nature that connected science to a wide range of domains. Making physics relevant was a mainstay of the philosophy of the program; Rutherford understood that relevance was necessary to make science appealing to all students through exposure to the exciting, relevant and captivating nature of the scientific enterprise.

Harvard Project Physics was one of the Alphabet (or ABC) Curricula produced as a national response to the Russian launch of Sputnik. (Such curricular were so labeled because of the many acronyms that identified the Science, Technology, Engineering and Mathematics [STEM] projects.) Welch (1979) estimates that by 1977 there were "more than 500 different projects" used in the United States high schools, and by 1972 Holton estimated that "300,000 students per year were using Harvard Project Physics" (Holton 2011). In hindsight, we find that twenty of these projects were widely used and only one, Biological Sciences Curriculum Study (BSCS) has survived and is still published and still in wide use as of this as of this writing.

Finally, and most notably, F. James Rutherford's impact on twentieth and twenty-first century science education through the visionary Project 2061**,** instrumental in directing and shaping all American science education programs**,** signals a significant personal accomplishment. Supported by the American Association for the Advancement for Science (AAAS), the massive and well-known seminal publications and research projects that collectively referred to as Project 2061 have established a framework for all states to follow.

Rutherford's success as a curriculum designer (Harvard Project Physics) was exceptional and intuitive in its inclusion of appropriate pedagogical content knowledge and for the remarkable range of multimedia and interdisciplinary components. HPP and the many other ABC curricula had unlimited funding support from the National Science Foundation (NSF) and many other private sources. The success of the HPP program established the authors, Rutherford, Watson and Holton, as leaders in American science education. Many others benefited from their authorship and participation in ABC curricula projects but only Rutherford was instrumental in efforts to establish a national, systemic science education initiative with the scope and sequence of Project 2061. These two significant accomplishments, HPP and Project 2061, identify Rutherford as one of the most influential science educators in American history.

Post-Sputnik Curricular Reforms

Rutherford wrote his own teaching materials, which included science stories specifically directed at students who had low-reading levels and little interest in science. At the 2005 Brandwein Lecture, Rutherford recounted the advantage of going beyond "the discipline-bound island of scientific information" of traditional textbook-centered instruction (Rutherford 2005, 270):

> Science is a grand human adventure, but you would not know it from reading science textbooks. In every science discipline there are stories to tell, ideas to explore and to try to understand, advances and disappointments to confront, applications to astound us or worry us, mysteries solved and new mysteries created-but that is not what comes through in science textbooks then or now. (371)

Rutherford was modifying a college textbook written by Harvard professor Gerald Holton for use in his high school classroom. That text, *Introduction to Concepts and Theories in Physical Science*, included astronomy, chemistry, the history of science and three chapters on the philosophy of science. While Rutherford was a graduate student at Harvard, he approached Holton and asked him if he would write a version of the book for high school students. Holton responded, "Why don't you do it?" (Holton 2011)

They agreed that Rutherford would attempt a revision with Holton monitoring the process, "and that would have been the end of it." (Holton 2011) But Holton, called to an emergency meeting at the National Science Foundation shortly after the release of the Soviet spacecraft, Sputnik, now had a fortuitous opportunity**.** He explains:

> We were implored by the NSF officials to throw ourselves, individually or in groups, into the awesome task of designing, writing, testing, re-editing and finally publishing a national high-school physics course. . . Everyone at the meeting was sensible enough to say "no." Except one. That's how I became the principal investigator of what we first called Harvard Project Physics. (Holton 2011)

Holton saw an opportunity to develop a "humanistic, historically orientated course" in physics that was not just "one damned thing after another, but a coherent story" made from the "thoughts and work of living beings." (Holton 2011) Holton pursued Rutherford and well-known science educator/scientist Fletcher Watson to join the project.

The resulting "affluent" and "ambitious" curriculum was so incredibly varied and extensive, even by today's standards. (Holton, 2011) A supporting staff of over one hundred and fifty people ran the project with one hundred and twenty advisors. Rutherford served as the executive director and senior author and editor of the project until 1971. HPP was so massive that a 42-page "Sears and Roebuck" catalogue was needed to order HPP materials (Holton 2011). Eventually large publishing companies took over the marketing and production of the ABC curricula. Today, teachers and districts have grown to expect the large-scale packaging of textbooks and supporting paraphernalia, but at the time, the HPP production was definitely groundbreaking.

HPP stood as one of the most notable projects of the post-Sputnik era because of its widespread use and because of the many products that were available for teacher and student use.
HPP was also well known for the excellent summer institutes that Rutherford organized. Holton elaborates:

> But the key for most such teachers was to take a paid-for leave to go to a six to eight-week summer institute at one of the many teacher training sites in various parts of the country, which we organized for many years. Thousands of teachers went through those-great for them, but as you can imagine, an additional burden above all on Jim Rutherford, who acted tirelessly throughout the project as its Executive Director (Holton 2011).

The high quality of the products was also part of the appeal. Rutherford hired designer Albert Gregory to incorporate historic depictions, photos and artwork to the pages of the materials. No expense was spared to include authentic historic documents such as Copernicus's *De Revolutionibus,* obtained directly from the library at the University of Krakow. Teacher participants attended fully paid six to eight week summer workshops that showed them how to use the materials. In turn, the teachers provided feedback that often resulted in modifications to the materials. Participating teachers felt distinguished, and in many schools, things were noticeably different. Peter Dow, curriculum historian and contributor to Man: A Course of Study (M:ACOS) a cross-disciplinary and cross-cultural social studies project for middle school and upper elementary grade describes what he noticed in his school:

> As a young teacher just beginning my career at the time, I vividly remember the impact of these innovative programs on the classroom. I first learned about the NSF's efforts when physics students in my school began building ripple tanks to examine wave motion and swinging pendulums from the rafters of the gymnasium to study the rotation of the Earth. This was very different from the textbook-based learning I had encountered in my own education. (Dow 1991, 3)

In realistic terms, Dow's experience supports what McCormick indicates were "pockets of excellence where well-trained teachers conducted wonderful new NSF science programs" (McCormick 1992, 18). Teachers should be the decision-makers and implementers of new ideas and they "determine how much value to attach to what they already do, how much changes will help their students, and how much energy and time they can invest to make the changes, given the organizational and personal constraints that they face daily" (Cuban 1993, 239). Studies conducted by Glanz (1979) and Kyle (1985) are consistent with many other findings that suggest teachers involved in the curricular surge had changed their philosophies and approaches remarkably little. Rutherford understood what teachers faced in the classroom from his own experiences and focused a great deal of attention to the construction of materials in HPP so teachers would be able to easily add what they wanted or needed to their existing classroom lessons.

Science education researchers differ on the impact of the reform era and specific effectiveness of individual projects such as HPP. There is agreement that the most reviewed and successful high school science projects were BSCS, Physical Science Study Committee (PSSC) and HPP. Despite his crucial involvement, Rutherford is critical of the overall success of HPP and the many other ABC projects of the era. He claims that science education did not mature in the post-war years to become all that they could have. Why? "Indeed much of what passed for research were short-term assessment of courses, materials, approaches, and projects having more to do with justification than with the advancement of knowledge." (Rutherford 2005, 375) Rutherford points to a lack of persistence that would have created a steady and thus enduring pace for successful reform and indicates that there were immature "exuberant ups and disconcerting downs" throughout the past fifty years of science education . (Rutherford 2005, 375) Notwithstanding such critical assessment, the unprecedented scope and scale of the post-Sputnik projects are in themselves worthy of historical note, as DeBoer points out:

> What made the science curriculum projects unique as an education reform effort was the scale of the endeavor and the extent to which the projects were actually completed and used in the schools. The national scope of the projects, the funding by the federal government, the widespread use of the courses across the country, and the involvement of noted scientists in the development of courses all made this effort unmatched in the history of American education. The new curriculum projects offered the opportunity to put into practice a number of principles of good education that thoughtful science educators had been advocating for decades but had been unable to implement successfully on a wide-scale basis. (DeBoer 1991, 166)

Unfortunately, many of the grant-funded projects lacked effective summative evaluation processes and procedures, making it difficult to determine how much students learned from the curricula. There was little or no attention paid to teacher attitudes and/or pedagogical implications of the new materials during the development and evaluation processes of the projects despite the disproportional amount of R & D resources directed towards teacher training. Following the release of the ABC curricula, throughout the late 1970's and early 1980's many researchers sought out ways to assess overall changes in science classroom instruction. A myriad of qualitative and quantitative data emerged. Rutherford makes a critical point:

> It is no surprise that a complex educational "system" made up of more than 95,000 schools in 16,000 school districts with three million teachers, serving 54 million students and costing over $400 billion dollars to operate would create daunting reform issues on all levels (Rutherford 2005, 376).

One of the compelling attempts to determine the overall impact the ABC curricula was the 1977 NSF survey which collected data from 7,000 teachers, principals, central office personnel and state supervisors and officials (Strake & Easley 1978). The NSF *1977 National Survey of Science, Mathematics and Social Science Education* used the percentage of program utilization by districts as a marker for determining the success of the programs (NSF 1978). This report found that HPP was used by 12% of the school districts in America. Over sixty studies of the effectiveness of HPP were evaluated by Wayne Welch and he determined that the most salient features of HPP were the contributions it made to "retention in science, participation of women**….** [Performance] on critical thinking tests and understanding of subject matter all showed improvement where the Project Physics curriculum was adopted" (Matthews 1994, 6). Fletcher Watson published over sixty articles, research papers and reports and directed fifteen doctoral theses on HPP (Holton 2011). In one of the most popular research claims, Hurd (1969) describe a general pattern of overall science teaching trends in the following chart that McCormick published:

FROM	TO
The textbook as the authoritative source of information	Laboratory data as a primary source of knowledge.
Everyday technology is presented as science.	"Pure" science is emphasized.
Many science topics studied briefly.	In-depth studies of fewer topics.
Laboratory activities used to verify concepts in textbook.	Laboratory activities used to collect data from which concepts are derived.
Deductive thinking is emphasized to arrive at "correct answers."	Inductive thinking is stressed in arriving at reasonable tentative answers.
Rote and receptive learning.	Discovery and inquiry learning.

Fig. 1 Summary of significant trends in science teaching approaches adopted from McCormick (1992, 21)

McCormick's insightful summary is a valuable gauge that demonstrates the bridge between the HPP and Project 2061 and helps to highlight the role that Rutherford played to carry ideas from one experience to another. Rutherford added many examples of pure science into a collection of HPP readers which contained relevant stories written by famous scientists. The immense supporting materials served the single purpose to deemphasize the textbook by offering teachers laboratory ideas and activities to promote discovery and inquiry learning. Rutherford directed the development of all HPP materials to fulfill all the criteria listed in McCormick's summary of trends. The trends described by McCormick are obvious in Project 2061 as well.

The debate over the effectiveness of the ABC projects has been over for at least twenty years. There is little to nothing written to document the history of the significance of the individuals that that participated as writers, leaders, advisors and directors of the ABC projects. The attention and promise that the projects held for making a difference in the quality of science instruction put pressure on science educators, scientists and other experts to excel in their fields and to deliver quality products. It was unmistakably a competent and prestigious playing field and market. Not yet captured in the science education literature is how this period of strong collaboration and team efforts impacted careers and science education as a discipline. Peter Dow, project editor of MACOS, tells the story of the development and life of MACOS in his exceptional book, *Schoolhouse Politics: Lessons From the Sputnik Era*. The National Association for Research in Science Teaching (NARST), the largest and oldest science education association in America, is currently working on a history of both the organization and a yet-to-be-determined history of science educators. Rutherford is working on a book about the history of science education. Clearly science education needs more research such as Dow has added to social studies education through his work on the history of MACOS.

There is no doubt that significant relationships were established during this post-Sputnik period and that some of the most respected science educators of the century were associated with this curriculum boom. Most educators continued as faculty and made greater contributions to the field at large or within specific domains. Others continued as curriculum specialists and writers or leaders in organizations. Rutherford's involvement in HPP had many lasting effects on his career.

Rutherford left Harvard in 1971 to join the faculty of New York University where he stayed until 1977. In 1975 he was elected President of the National Science Teachers Association. Between 1977 and 1984 he served in two federal government positions. First he served as the Assistant Director of the NSF Education programs and then as Assistant Secretary of the Department of Education, National Center for Educational Statistics, the Fund for the Improvement of Post-Secondary Education.

Project 2061 (1985-2061)

In 1985, Rutherford was invited to join the American Association for the Advancement of Science to develop "plans and actions to give life to the AAAS's desire to engage the scientific community energetically and knowledgeably in a sustained K-12 science education reform effort" (Rutherford 2011). Rutherford was perfect for such an appointment with his diverse background as a science teacher, curriculum developer, professional development facilitator, university professor of science methods, grant writer, researcher, author, government education officer and reform leader. He fully appreciated the value and meaning of this new position and stated:

> It is from those experiences that I acquired a set of beliefs about science education reform-some fortifying my existing convictions, other changing them-that eventually led me to my role in the creation of Project 2061 and its first product, *Science for All Americans* (Rutherford 2011).

He believed that the AAAS was the right organization for this work as well. It's large membership cuts across all scientific areas and it was held in high regard globally, and by science policy makers worldwide. Because Rutherford had experience working in many different settings, he carefully weighted the association of this project to the AAAS.

The AAAS's board of directors is composed of outstanding scientists, most of whom care about and are informed on science education from K-12 to post-doc; its journal *Science* reaches scientists and science educators throughout the world; and being over a hundred years old, it seems likely to be in business for decades to come (Rutherford 2011).

The ultimate aim of Project 2061 is long-term commitment (hence the use of the year 2061, the year of the return of Halley's Comet) that will lead to sustaining science, mathematics and technology reforms that facilitate the attainment of scientific literacy for all K-12 students by the time they graduate from high school. According to the goals outlined by Project 2061, the definition of science literacy is:

> "Science" in science literacy was to be broadly conceived to include the physical, biological, and social sciences, and the interrelationships among those sciences and mathematics and technology (Rutherford, 2011).

To achieve a scientific literate body of K-12 students and future American citizens, Project 2061 has created explicit learning goals that are compelling and challenging but attainable. The explicit learning goals are published in *Science for All Americans* and are "final rather than accumulating grade-band learning goals and without reference to teaching methods or materials" (Rutherford 2011). Most strongly stated is the determination that this accomplishment is to "be generated without involvement of or financial support from the federal government, in order that their authority will derive from the scientific community rather than from any agency of government" (Rutherford 2011). In order to create a systemic reform effort Rutherford relied on three valuable lessons from his other endeavors and career experiences and so was seeking to address the following problems that had stopped reform in the past:

1. Sustainable science education reform needs to be steady rather than fragmented
2. There needs to be a national consensus on the direction that science education should take.
3. There are no short term or impatient solutions; effective reform requires long-term commitment from all involved.

With these issues in mind, Rutherford led the way to create reform tools for state, local and national curriculum revisions. What is a reform tool? Project 2061 consists of a series of publications (products) and web-based resources and currently includes *Science for All Americans, Benchmarks to Science Literacy, Blueprints for Reform*, *Resources for Science Literacy*, *Designs for Science Literacy, and Atlas of Science Literacy (I & II)*. These products differ considerably one from another. There are many other reports, studies, collaborative activities and resources.

Unlike curricular documents that spell out in vivid detail what science teachers should teach, fact by fact, Project 2061 "argues that less, not more, should be taught in schools" (Massey 1990, 59). It contains information about how one idea in science is connected to another through a subjective voice that professes the need for earthy stewardship.

With a consensus of what science literacy means, Rutherford began to pull educators, scientists, administrators, mathematicians, engineers, historians, and learning specialists to produce the book that would allow districts and teachers the tools they needed for "fashioning their own curricula (AAAS, 1990)". This idea of setting a baseline, from which teachers can then individualize their programs to suit their needs and styles, is similar to the premise that Rutherford made in HPP. The goal of the "common conceptual focus" is stated in the preface to the book (AAAS 1990, x):

> *Science for All Americans* is the result of a three-year collaboration involving several hundred scientists, mathematicians, engineers, physicians, philosophers, historians, and educators. It is, we believe, as close as it is possible to come to valid expression of the view of the science community on what constitutes literacy in science, mathematics, and technology.

In an interview with the author, Rutherford describes the complex process of the production of *Science for All Americans*,

> Five independent science panels met regularly over this same period, to revise and rewrite the document as the panel of experts progressed. The panels examined five domains (Biological & Health Sciences, Mathematics, Physical & Information Sciences & Engineering, Social & Behavioral Sciences, and Technology) and were required to defend their positions according to scientific and educational significance. Consultants were invited to speak. In the end, the panels submitted drafts of reports on their decisions, which were sent to 130 highly qualified individuals and to the National Council for additional review. The final stamp of approval was issued after each of the AAAS Board of Directors read the document.

Science for All Americans was not a summary of these panel reports, but an "independent synthesis based on their recommendations." (Massey 1990). *Science For All Americans* was released in 1989 and then again in 1990 to align with *Benchmarks for Science Literacy*, the second book of Project 2061.

Several years following the release of *Science for All Americans*, and greatly influenced by the publication, the National Science Teachers Association and the National Academy of Sciences asked the National Research Council to coordinate the development of the national science education standards (NRC 1996, 14). The *National Science Education Standards* was a specific directive for *wha*t should be taught, and its sister companion, *Inquiry and Learning: A Guide for Teaching and Learning Science* (NRC 2000) focused on ***how*** science should be taught with Project 2061, thus providing the tools to guide all states to uniformity in K-12 science. Rutherford, as director and leader of Project 2061 had fulfilled the planned objectives upon joining the AAAS in 1985 in the "sustained K-12 science education reform effort" that would engage a scientific community (Rutherford 2011).

Lee and Paik (2000 17) believe there are five key reform documents that currently shape American education and include three assessment studies along with Project 2061 and the National Science Education Standards in the comprehensive analysis. They state "that *Science for All Americans* by Project 2061 (AAAS 1989) represented a major milestone in shaping the discourse of science education reform since the late 1980". Koppal and Caldwell (2004) provide valuable information about some of the tools of Project 2061: they indicate that *The Atlas of Science Literacy* (AAAS 2001a) "provides a collection of linked conceptual strand maps displaying the sequence of ideas that contribute to a sophisticated understanding of some key science and mathematics topics" (Koppal and Caldwell 2004, 29). *Designs for Science Literacy* (AAAS 2001b) "offers suggestions for restructuring time, instructional strategies, and content that can lead to very different kinds of curricula serving a common set of learning goals" (Koppal and Caldwell 2004, 29). These useful tools were the final products that spring at root, from Rutherford's core beliefs clarified long before he retired as the director of Project 2061.

Under the current leadership, Project 2061 hosts conferences to assist curriculum reformers with participants ranging from teachers, policy makers, textbook publishers and researchers. They have developed a partnership through an NSF-funded grant with Michigan State University, Northwestern University and the University of Michigan to create the Center for Curriculum Materials in Science. The purpose of the Center is to conduct significant research on issues related to "the design, analysis, and use of science materials, while also preparing a new generation of leadership through innovative graduate and postgraduate programs" (Koppal and Caldwell 2004, 29). Project 2061 has also been developing strategies and tools for evaluating the alignment of K–12 assessments in science and mathematics with national and state standards and benchmarks. A five-year comprehensive study provided data about testing has developed and offered an assessment analysis methodology to determine the alignment of K–12 science and mathematics assessment items to national and state standards. The Project 2061 team has begun an Interagency Education Research Initiative with the University of Delaware and Texas A & M to study the best ways to coordinate curriculum, teaching methods and professional development to improve student learning outcomes in mathematics. Most recently, Project 2061 has established a parent portal with recommendations for families and communities as a response to international studies that point out American apathy towards science education.

Project 2061 is based on several deeply-held beliefs promoted by Rutherford's influence. One is that the terms and circumstances of human existence can be expected to change as much and as unpredictably from 1985-2061 (coincidentally the approximate average human life span) as they did from 1910 to 1985 or 1835-1910. Science and technology will continue to be at the center of social and economic change-causing it, shaping it, responding to it. Science education will thus become ever more imperative in preparing individuals and societies for the current time and for their futures. Finally, there is a belief that science education is not now meeting that challenge and therefore must itself undergo extensive and insightful reform locally as well as globally.

At the outset, Project 2061 was an American undertaking to foster science literacy in its own people. With time, however, it became widely known outside of the United States. The Europe-based Organization for Economic Cooperation and Development studied Project 2061 in 1989 and characterized it as the "single most visible attempt at science education reform in American history" (Allman 1993). Translations of Project 2061 publications have been made in Asia, Europe, and Latin America. New Zealand researcher John Clark used the theoretical premises of Project 2061 to support a call for reform in teacher preparation programs in New Zealand that he believes are:

> overstuffed and undernourished with too much emphasis on a detailed understanding of the nuts and bolts of individual components of the mandated curriculum and far too little emphasis on the more fundamental contextual aspects of the curriculum such as historical determinants, sociological influences, philosophical justifications and political motivations (Clark 2005, 520).

Rutherford stepped down as Education Director of the AAAS and Project 2061 in 1998 and retired from the AAAS in 2001. It is clear that his contributions to science education reform were crucial to the success of advancing scientific literacy, and that his determination and his clear-cut and clearly-stated goals have inspired many schools to obtain high quality science programs.

Conclusion

This study attempted to present an account of a science educator whose great influence on a pivotal physics curriculum, Harvard Project Physics and his subsequent work, Project 2061 is unprecedented and sadly, mostly unknown. This research describes the impetus that drove one man to devote a very significant amount of intellectual energy to a reform process to facilitate the creation of quality K-12 science in the twentieth and twenty-first century. Under his direction science education reform would proceed with the foundational ideals and pedagogical tools in place to give consistency and direction for sustained and long-term effects.

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