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Does Doing Scientific Research in High School Correlate with Students Staying in Science? A Half-Century Retrospective Study

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Abstract The American Association for the Advancement of Science (AAAS) has declared in an advertising campaign that "you can't start young enough" in science. However, there is no long-term data evaluating the effect of early exposure to original scientific research on producing career scientists. To address this issue, we examined a hands-on summer science research program for high school students that ran from 1958 to 1972. We compared participants in that program with science students that only began their hands-on research experience once in university. Our data indicate that students who are interested in science and have an opportunity to participate in original scientific research while in high school are significantly more likely ($p<.005$) to both enter *and* maintain a career in science compared to students whose first research experience didn't occur until university. Our data suggest that more hands-on high school science research programs could help increase the number of students entering and maintaining scientific careers, relieving the growing concern that North America is losing its leadership status in the international scientific community.

Keywords Careers · Experience · Headstarting · High school · Research

Introduction

Each edition of the journal *Science* includes an advertisement to become a member of the American Association for the Advancement of Science (AAAS). The advertisement depicts Einstein morphed into an infant with the simple slogan "Science: You can't start young enough" (http://parafoniades.files.wordpress.com/2006/12/baby-genius-psa.jpg). This "Baby Genius" has become something of a mascot for the scientific community and the idea that one is never too young for science could be considered an AAAS motto. But is the caption for this image in fact true?

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Here we explore the value to the scientific profession of starting youth interested in science in original research during high school. The idea that a lifelong interest in science is most likely to develop in childhood has been previously addressed (Russell et al. 2007). It has been reported that undergraduates benefit from participating in scientific research. Additionally, it has been demonstrated that undergraduate research opportunities increase students' interest in science, technology, engineering, or mathematics careers in the short term. Hanauer et al. (2006) suggested that a "similar benefit may be expected for high school students" (p. 1880) and Russell et al. (2007) presumed that a good time to attract students to science would be in elementary school. As reasonable as this sounds, these claims have yet to be supported by long-term data.

Papers that report a benefit of doing science as an undergraduate look at the level of interest in science and the likelihood that undergraduates who participated in scientific research went on to graduate school (see, for example, Russell et al. 2007). In addition, it has been shown that students with an early interest in science (i.e., grade 8 or earlier) will be more likely to enter a career in science (Tai et al. 2006). That study, though, only addresses interest in the subject of science, not the execution of scientific research.

While many studies emphasize the importance of attracting students to science early (Hanauer et al. 2006; Russell et al. 2007), there are no data exploring whether participation in hands-on research during high school (or earlier) truly increases the probability of not just entering science, but establishing a lifelong career in the field. It is, in fact, possible to imagine that starting students too early in true science as an activity may disillusion them. Adult resistance to science frequently has origins in childhood (Bloom and Weisberg 2007). Scientific enquiry typically requires repetition in order to get an adequate sample size and verifiable results. This repetition can be tedious and monotonous for adolescents and younger children. Although the Baby Genius image asserts that one cannot start in science too young, it is patently absurd to believe that an infant could understand a null hypothesis or what it would mean to design and execute a controlled experiment. Starting in science young could inspire children to a career in the field. However, starting in science too young might lead students to reject science as a career because of the monotony of the methodology or the tedium of its execution.

Here we explore whether there is any association between participation in scientific research and later career paths for 11th and 12th grade students who expressed an early interest in science. We are not only interested in the exposure of students to established scientific knowledge, but also in their exposure to science as a methodology via original research. We wish to know whether a positive participatory experience in original research in an established research laboratory during high school correlates with a long-term career in science.

A multitude of programs in the USA since the end of the Cold War have provided high school students with opportunities to do research in a laboratory setting before entering university. Several studies have shown that the students appreciate the opportunity and that many, if not most participants, continued their education in a scientific field (Gibson and Chase 2002; Hanauer et al. 2006; Helm et al. 1999; Markowitz 2004). However, no studies have followed up on the participants throughout their careers to assess the long-term effectiveness of such programs. We know of no data showing that individuals who begin scientific research while in high school are more likely to stay in science than those who begin such laboratory experience later, when in university.

Here we undertake a retrospective study of a hands-on research program for high school students run in the middle of the last century. Our goal is to determine the long-term effectiveness of such programs on students who were already interested in pursuing science.

We are not asking whether the research experience raised interest in science. Rather, we are asking if it has a durable impact that lasts over decades.

Materials and Methods

We compared two groups of former students. The experimental group was drawn from participants of the National Science Foundation (NSF) sponsored Thayer Academy Advance Studies in Science program, which ran from 1958 to 1972 in Braintree, Massachusetts. The names of 706 participants of the Thayer program were acquired from Thayer Academy. Of these, 227 were located via Google and participated in our study.

The Thayer Academy Advance Studies in Science program placed selected high school students in active research laboratories for eight weeks during the summer between their 11th and 12th grades. In order to be admitted to the program students had to fill in an application, write a statement about both their interest in science and long-term goals, plus submit a letter of reference from a science teacher. Grades were taken into consideration and applicants were interviewed by a selection committee made up of staff at Tufts and Thayer. While the program was open to all students, there were some implicit economic constraints. The students who were in the program did not earn any money, and if it was essential that a student had to work for money, that would have limited their likelihood of applying for the program.

The students were drawn from both public and private schools around the Braintree, MA area. Students had to live close enough to Braintree, MA to be able to commute daily by either public or private transportation to Thayer Academy and their research placements.

The students were expected to participate directly in the laboratory's research activities. An important part of these placements was that the students were involved in original research. Students were placed in physics, chemistry, biology, engineering, biochemistry, or biophysics laboratories. The objective of the program, as stated in the Advance Studies in Science Report of 1962 was "to familiarize students with on-the-job problems of initiating, planning, and conducting research" (Thayer Academy 1962). Some of the aims of the program were to familiarize the students with basic research tools, laboratory techniques, and allow students a venue to pursue their interests by advanced studies. Some of the research was of high enough quality to have been published (e.g., Estes and Wassersug 1963).

The control group was comprised of graduates from Tufts University (Medford, Massachusetts), who received BSc or BSE degrees from 1960 to 1976. Their contact information was provided by the Tufts University Alumni Office and 363 agreed to participate in our survey. In order to be of comparable status to the Thayer program participants, we only include those who could also be located via Google. This yielded a final control group of 344.

Tufts University graduates were specifically chosen as our control group because Tufts is a high quality research university also in the Boston area, with strong undergraduate programs in both science and engineering. Also, it is both a science and arts university. Tufts thus provided students with alternatives to a scientific degree so they were free to change their educational pathway, which would have been more difficult if our control group were drawn from students at a primarily science and engineering university (such as MIT). During the 1960s and 70s, Tufts drew most of its students from the same geographic region as Thayer Academy. The two schools had close links as well through the Advanced Studies in Science Program. Tufts' faculty gave introductory lectures in the programs and provided several of the laboratories where the students had their research placements. Most importantly, many of

the graduates from the Thayer program attended Tufts University likely due to the association at that time between the two academic institutions. The sampling years for the two groups were offset, however, so that the comparisons were between people who attended university at the same time. Participants from both groups were asked whether they entered the field of science or engineering upon graduating from university, and whether they maintained a career in science or engineering in subsequent decades.

Responses from both participant groups were categorized by the two authors. Scientists were defined as those people who were actively researching in their field, were involved in technology development, or were engineers. Medical doctors, veterinarians, and teachers, who were not or had not sustained a research program for at least a decade, were not considered scientists for the purpose of this study.

Results

A Chi-squared test revealed that students in the Thayer group were significantly more likely to continue in science and pursue investigative careers in the field than science graduates without the high school experience (χ^2=8.55; p<.005) (Table 1). This difference was significant whether or not we included with the Thayer group nineteen graduates from Tufts University, who had participated in other high school summer science programs. Science students who begin research while in high school are thus more likely than those who start in university to remain in research for the duration of their career.

When the Thayer program was running, males were far more common than females in science. Indeed there were significantly more males than females in both groups (χ^2=43.8; p<.001) with proportionately more males in the Thayer population (χ^2=30.34; p<.001). A separate analysis by gender, however, showed that the influence of high school research could not be accounted for solely by disproportionately high numbers of males in the Thayer program (χ^2=2.62; p>.1 for both sexes).

Conclusions

We recognize that this type of retrospective study has limitations, however to explore this topic more rigorously would take a longitudinal prospective study that would require

Table 1 Data comparison between students interested in science with and without research experience in high school in terms of their likelihood of becoming career scientists

	Became career scientists	%	Did not become career scientists[a]	%
Research experience in high school[b] (N=246)	134	54.5	112	45.5
No research experience in high school (N=344)	142	41.3	202	58.7

[a] This included 21 students who started their career in science but left within approximately 10 years.

[b] Significant at the p<.005 level (χ^2 =8.55). Note: 19 students from Tufts (the "no research experience" group), who had been in high school summer science research programs other than the Thayer program, are included within the 227 Thayer students (the "research experience" group) and excluded from the "no research experience" group. If these students are excluded altogether from consideration, the difference between the two groups remains significant at the p<.005 level (χ^2 =8.725).

decades to execute. We acknowledge the possibility of bias in the selection method we used and the possible self-selection bias of the participants. Additional variables undoubtedly affect whether students who participated in high school science research programs continue in a scientific career. For example, economic considerations, employment opportunities, and family pressure can all affect whether people remain in science. However, to the best of our knowledge our data are the only ones that address the issue of whether early exposure to hands-on science is associated with a later career in scientific research.

We recognize that our data may not apply to all high school students. The correlation we present is restricted to students who had an established interest in science in high school. For these students, early participation in research increased the likelihood that they would enter and maintain a scientific career. Our data do not attempt to identify a specific age at which the majority of students interested in science may be too young to be active in a research laboratory setting and find the experience overall positive.

These results have implications for the long-term maintenance of scientific activity and excellence in North America. The Thayer program was initiated after the launch of Sputnik as part of a national initiative in the USA to catch up with the Soviets in the space race (Litchfield, pers. comm.). Although the Soviet Union no longer exists, there is growing concern in North America and Europe that Asian countries are becoming scientific powerhouses that may one day dominate North American and European science (Alexander 2005; Anonymous 2007; Broad 2004). There are concerns in the United States about the number of American scientists in leadership roles in the scientific community (NRC 2005; Tai et al. 2006).

The decision by NSF in 1972 to cease funding programs that headstarted high school students in research was made without any evidence that such programs were ineffective. Rather it was based upon a new policy at NSF to only fund programs at or above the university level (Litchfield, pers. comm.). Some similar programs to inspire high school or younger students have been reestablished since 1972 by the NSF on a limited basis through their education division. None of these, however, appear to be of the magnitude or scope of the Thayer program. Based on the data provided here, as well as concerns about the future quality and quantity of scientific discoveries, we suggest that it may be time for the NSF to expand such programs. Other countries striving for more of their citizens to become career scientists might similarly explore promoting opportunities for their high school students to work in research labs.

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